



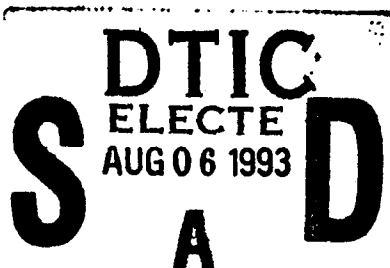
AD-A267 657



2



Midwater bioluminescence
assessment in the West Alboran Gyre
(Mediterranean Sea)



Technical Report

by

E.A. Widder
Principal Scientist

Funding was provided by Grant No. N00014-90-J1819
from the Office of Naval Research

Approved for public release; distribution unlimited.

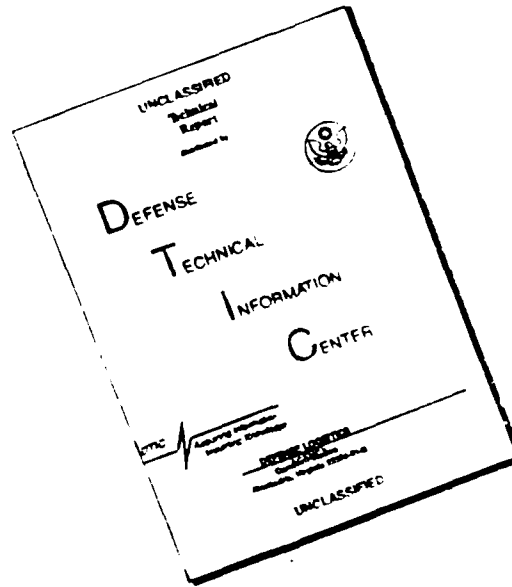
(2)

93-17708



93 8 3 262

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST
QUALITY AVAILABLE. THE COPY
FURNISHED TO DTIC CONTAINED
A SIGNIFICANT NUMBER OF
PAGES WHICH DO NOT
REPRODUCE LEGIBLY.

DOCUMENT DATA SHEET

AUTHOR WIDDER, E.A. <u>et al.</u>	PUBLICATION DATE SEPTEMBER 1991
TITLE Midwater bioluminescence assessment in the West Alboran Gyre (Mediterranean Sea)	
REFERENCE Harbor Branch Oceanographic Institution, Cruise Report R/V Seward Johnson April 5-25, 1991 Cruise No. 90-092	
ABSTRACT The primary research objective was a detailed analysis of bioluminescent phytoplankton and zooplankton distributional patterns in the Western Alboran Sea. Bioluminescence potential of the water column was assessed at 17 different stations using a vertical profiling bathyphotometer (HIDEX-BP). Organism collections, for purposes of taxonomic identification and physiological experiments were made by meter net tows, SCUBA and using the Johnson-Sea-Link submersible. Emphasis was on the identification of gelatinous zooplankton as potential sources of bioluminescence.	
KEYWORDS ALBORAN SEA BATHYPHOTOMETER BIOLUMINESCENCE CTENOPHORES GELATINOUS ZOOPLANKTON JOHNSON-SEA-LINK MEDUSAE SEWARD JOHNSON / RV SIPHONOPHORES SUBMERSIBLES	
ISSUING ORGANIZATION Harbor Branch Oceanographic Institution 5600 Old Dixie Highway Fort Pierce, Florida 34946 Telephone: (407) 465 2400	

TABLE OF CONTENTS

Scientific Personnel	4
Ship's Personnel.....	4
Track Chart.....	5
Station List.....	6
Objective.....	7
Itinerary	7
Activity Log	8
Results.....	10
Vertical Profiles.....	10
Horizontal Transects.....	10
Figure 1.....	11
Figure 2.....	13
Figure 3.....	14
Gelatinous zooplankton	15
Scuba Collections	15
Submersible Collections.....	22
Hydromedusae.....	30
Ctenophores	32
Siphonophores.....	33
Laboratory Measurements of Bioluminescence.....	35
Photon Counting and CCD Spectra	35
OMA spectra	36
Imaging the bioluminescence of the gelatinous midwater fauna.....	37
Conclusions.....	39
Acknowledgements	39

Appendix A - HIDEX-BP Profiles

Appendix B - HIDEX vs. LoLAR Profiles

Appendix C - Transects

Appendix D - Solar Irradiance

Appendix E - Distribution and Taxonomy of Zooplankton in the Alboran Sea and
Adjacent Western Mediterranean: A Literature Survey and Field
Guide. By Laurence P. Madin

DTIC QUALITY INSPECTED 3

Accession For	
NTIS	CRA&I <input checked="" type="checkbox"/>
DTIC	TAB <input type="checkbox"/>
U:	announced <input type="checkbox"/>
Justification	
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

Scientific Personnel

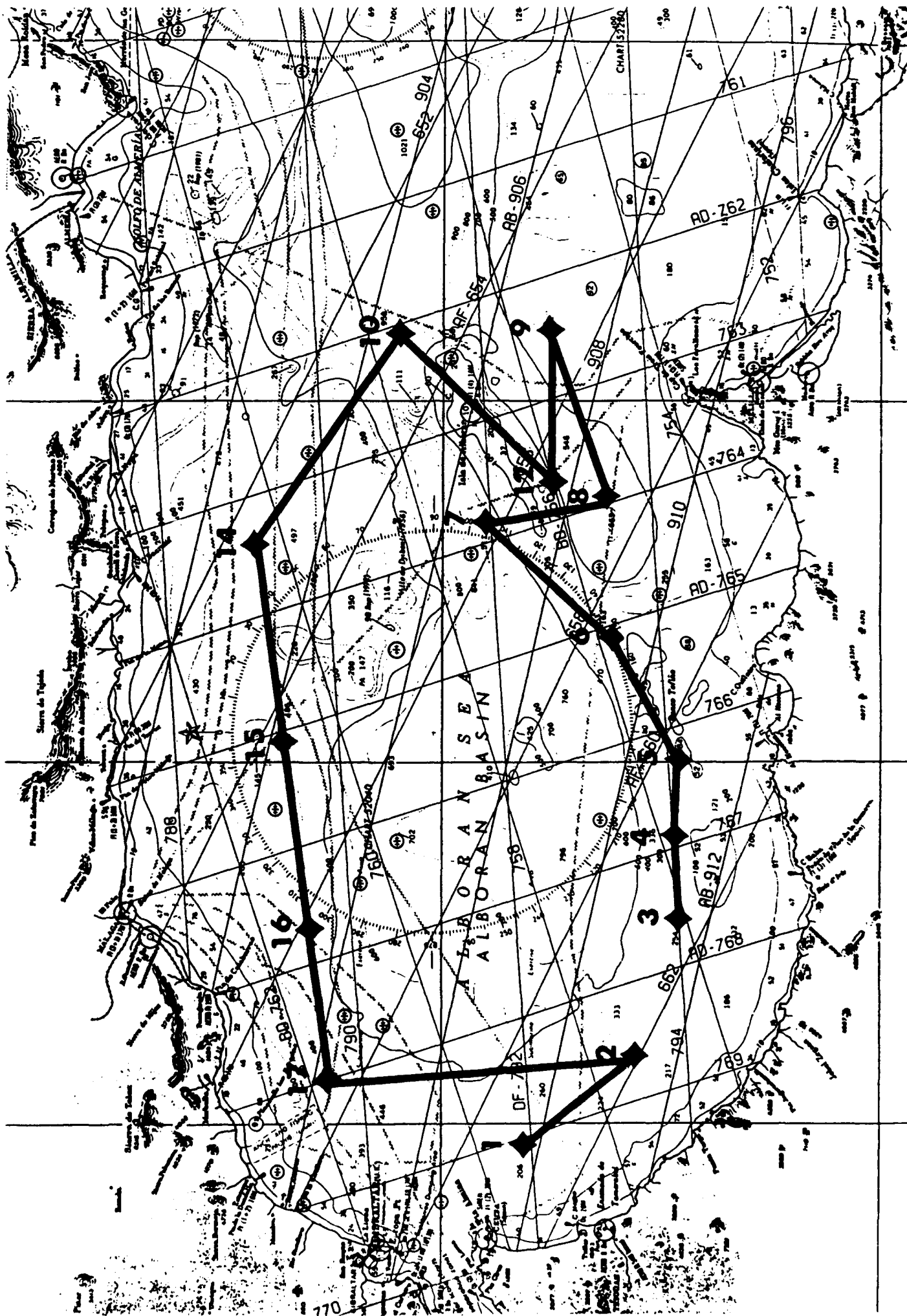
J. Case,	Scientist, Univ. of Calif., Santa Barbara
S. Bernstein,	Scientist, Univ. of Calif., Santa Barbara
R. Beard,	Engineer, Univ. of Calif., Santa Barbara
S. Haddock,	Graduate Student, Univ. of Calif., Santa Barbara
P. Herring,	Scientist, Inst. Oceano. Sci. U.K.
P. Pugh	Scientist, Inst. Oceano. Sci. U.K.
C. Mills	Scientist, Friday Harbor Labs, WA
R. Harbison	Scientist, WHOI
M. Latz	Scientist, CBI, Johns Hopkins Univ.
M. Ramdani	Foreign Observer, Institut Scientifique, Rabat, Morocco
M. Menioui	Foreign Observer, Institut Scientifique, Rabat, Morocco
E. Widder,	Chief Scientist, HBOI

Ship's Personnel

D. Schwartz	Captain
R. Van Hoek	First Mate
P. Zobel	Mate
G. Fisher	Engineer
M. Laskowski	Asst. Engineer
W. Thomas	Seaman
R. Bird	Seaman
M. Clark	Seaman

Sub Crew

D. Liberatore	Operations Director / Pilot
C. Caddigan	Pilot
J. Sullivan	Electronics Supervisor
J. Buckley	Tech
K. Rehak	Tech
M. Parker	Tech



Station List

Station	Location	Date
1	35° 49.5' N; 5° 03.8' W	24 April
2	35° 33.5' N; 4° 48.7' W	23 April
3	35° 28.0' N; 4° 27.5' W	6 April
4	35° 27.1' N; 4° 12.5' W	7 April
5	35° 28.0' N; 4° 00.0' W	8 April
6	35° 34.9' N; 3° 39.7' W	9 April
7	35° 54.3' N; 3° 21.0' W	10 April
8	35° 35.5' N; 3° 16.0' W	11 April
9	35° 44.8' N; 2° 48.1' W	12 April
10	36° 03.5' N; 2° 48.0' W	17 April
12	35° 45.0' N; 3° 14.5' W	13-16 April
14	36° 29.5' N; 3° 22.5' W	19 April
15	36° 21.0' N; 3° 55.5' W	20 April
16	36° 17.2' N; 4° 27.5' W	21 April
17	36° 13.2' N; 4° 59.2' W	22 April

Objective

The primary research objective for this cruise was the mapping of bioluminescence potential in the Western Alboran Sea including a detailed analysis of the distributional patterns of the phytoplankton and zooplankton contributing to this signal.

Itinerary

RV *Seward Johnson* arrived in Cadiz, Spain on April 3 at 20:30. Planned arrival had been April 2 but ship was delayed due to bad weather during crossing. Scheduled departure was for the morning of April 4. Actual departure was midafternoon April 5. Delay was primarily due to the need to acquire appropriate clearance from U.S. Embassy in Madrid for ship to refuel at Rota. This clearance was separate from diplomatic clearance from Spain needed to work in their waters. We had not been advised of need for this particular clearance by either the state department or ONR ship ops.

Our area of operation is a designated "submarine exercise area" therefore U.S. Navy clearance was required for each dive site. In order to stay on schedule with the USNS *Bartlett* which was working each station 48 hrs ahead of us Stations 1 and 2 were skipped and we proceeded immediately to Station 3 for our first dive on April 6. The dive schedule was two dives per day between noon and midnite. During the cruise clearance was requested, via the *Bartlett*, to return to Stations 1 and 2 at the end of the cruise when we had two unscheduled days.

Schedule proceeded with two dives per day at each station until April 13 when we rendezvoused with USNS *Bartlett* for 4 consecutive days of operations planned at Station 12. On April 17 three dives were conducted at Station 10. No dives were conducted April 18-22 due to bad weather, however, HIDE-X-BP profiles and net collections were possible on all but one of these days (April 18 at Station 13). Weather improved and dives were conducted on the final two days of operations (April 23 and 24) at Stations 1 and 2. All scientific personnel were off-loaded in Rota on April 25 along with some of the scientific equipment. Special clearances were required in order to off-load foreign nationals on the U.S. Navy base. Military airlift of HIDE-X-BP, winch and associated gear from Rota to Iceland went according to schedule.

ACTIVITY LOG - R/V SEWARD JOHNSON
MED-OP '91 6-APR-91 - 24-APR-91

Activity No.	Date	Time GMT + 2	Station	Activity	Comments
01	4/6	12:10	3	Plankton Tow	64 μ m mesh 5 m Abundant <i>Noctiluca</i>
02	4/6	13:00	3	JSL Dive 2929	WIDDER/MILLS
03	4/6	14:50-15:00	3	HIDEX	Day Test
04	4/6	21:20-22:10	3	HIDEX	
05	4/6	22:50-01:30	3	JSL Dive 2930	BERNSTEIN/WIDDER
06	4/7	01:40-01:45	3	Plankton Tow	Vertical Cast 0-200 m
07	4/7	02:00-03:30	3	HIDEX	
		GMT			
08	4/7	12:30-15:40	4	JSL Dive 2931	PUGH/RAMDANI
09	4/7	12:30	4	Surface Sample	<i>Noctiluca</i> collection
10	4/7	19:30	4	HIDEX	Peak @ 25, 65, 95 m
11	4/7	20:30-24:00	4	JSL Dive 2932	WIDDER/HERRING
12	4/8	00:30-01:00	4	Plankton Tow	0-200-0 m Vertical
13	4/8	01:00-02:00	4	HIDEX	
14	4/8	02:50	4	Plankton Tow	25 m - Few <i>Noctiluca</i>
15	4/8	12:20	5	Plankton Tow	5 m/ 5 min Abundant <i>Noctiluca</i>
16	4/8	12:35	5	Plankton Tow	5 m/ 30 s Abundant <i>Noctiluca</i>
17	4/8	13:00	5	JSL Dive 2933	HARBISON/MENIOUI
18	4/8	19:00-20:00	5	HIDEX	
19	4/8	21:00	5	HIDEX	5 miles off sta due to fishing nets
20	4/8	22:00-0:30	5	JSL Dive 2934	HERRING/WIDDER
21	4/8	01:30-03:00	5	HIDEX	w/pump
22	4/9	12:00	6	Plankton Tow	5 m - Abundant <i>Noctiluca</i>
23	4/9	13:00	6	JSL Dive 2935	MILLS/HADDOCK
24	4/9	19:45-20:10	6	HIDEX	
25	4/9	20:30	6	JSL Dive 2936	BERNSTEIN/LATZ
26	4/10	12:00	7	Plankton Tow	5 m - Abundant <i>Noctiluca</i>
27	4/10	12:30	7	JSL Dive 2937	PUGH/BEARD
28a	4/10	17:30	7	SCUBA Dive	Abundant ctenos
28	4/10	19:00-20:00	7	HIDEX	Dusk series
29	4/10	20:30-23:30	7	JSL Dive 2938	WIDDER/HERRING
30	4/11	00:45	7	HIDEX	
31	4/11	12:10	8	Plankton Tow	5 m - Abundant <i>Noctiluca</i>
32	4/11	12:30	8	JSL Dive 2939	HARBISON Rough Seas
33	4/11	19:30-20:00	8	HIDEX	
34	4/11	21:15	8	JSL Dive 2940	HERRING/BERNIE LoLAR dead
35	4/12	13:10	9	JSL Dive 2941	MILLS/MENIOUI
36	4/12	17:00	9	Plankton Tow	5 m-Abundant Noct & <i>Protopteridinium</i>
36a	4/12	17:15-18:15	9	SCUBA Dive	Abundant Beroe @ surface
37	4/12	19:00-20:00	9	HIDEX	
38	4/12	20:50-00:10	9	JSL Dive 2942	BERNSTEIN/HADDOCK
39	4/13	00:59-01:30	9	HIDEX	

40	4/13	13:30	12	JSL Dive 2943	PUGH/RAMDANI
41	4/13	17:00	12	Plankton Tow	5 m - Abundant <i>Noctiluca</i>
42	4/14	11:00	12	JSL Dive 2944	HARBISON/BEARD
43	4/14	14:15	12	Plankton Tow	
43a	4/14	16:10-17:00	12	SCUBA Dive	@ Surface
44	4/14	17:50	12	HIDEX	
44a	4/14	18:45-21:30	12	JSL Dive 2945	WIDDER/BERNSTEIN Flyover
45	4/14	22:42-00:38	12	HIDEX	
46	4/15	01:15	12	Plankton Tow	30 m
47	4/15	11:00	12	JSL Dive 2946	MILLS/MENIOU
48	4/15	17:15	12	SCUBA Dive	High Abundance
48a	4/15	19:00	12	JSL Dive 2947	WIDDER/BERNSTEIN Flyover
49	4/15	18:30	12	HIDEX	
49a	4/15	23:30-00:20	12	HIDEX	
50	4/16	00:40	12	Plankton Tow	30 m
51	4/16	12:30	12	JSL Dive 2948	HADDOCK/RAMDANI
52	4/16	17:30	12	SCUBA Dive	
53	4/16	20:00	12	HIDEX	
54	4/16	21:30	12	JSL Dive 2949	BERNSTEIN/HERRING
55	4/17	01:30	12	HIDEX	
56	4/17	02:15	12	Plankton Tow	20 m
57	4/17	12:30	10	JSL Dive 2950	PUGH/MILLS
58	4/17	15:00	10	SCUBA Dive	"Oceanic" water
59	4/17	16:30	10	JSL Dive 2951	Training Dive
60	4/17	20:30	10	HIDEX	Lower BL
61	4/17	22:00	10	JSL Dive 2952	HERRING/WIDDER
62	4/18	00:45	10	HIDEX	
63	4/18	01:15	10	Plankton Tow	50 m
64	4/19	19:00-19:45	14	HIDEX	
65	4/19	20:00	14	Plankton Tow	40 m
66	4/20	23:00-23:20	15	HIDEX	
67	4/20	23:25	15	Plankton Tow	5 m
68	4/21	21:30	16	HIDEX	
69	4/21	23:45	16	Plankton Tow	5 m and 20 m
70	4/22	20:30-22:00	17	HIDEX	
71	4/22	22:45	17	Plankton Tow	20 m
72	4/23	00:00-01:05	17	HIDEX	
73	4/23	14:10	2	JSL Dive 2953	HARBISON/HADDOCK
74	4/23	18:10	2	SCUBA Dive	
75	4/23	18:25	2	Plankton Tow	5 m
76	4/23	20:00	2	HIDEX	
76a	4/23	21:30	2	JSL Dive 2954	WIDDER/HERRING
77	4/24	01:00-01:15	2	HIDEX	
78	4/24	01:30	2	Plankton Tow	15 m
79	4/24	03:45-04:00	1	HIDEX	
80	4/24	04:10	1	Plankton Tow	15 m
81	4/24	07:30-10:30	1	JSL Dive 2955	MILLS/BERNSTEIN

Results

Vertical Profiles

EAW

Bioluminescence potential was mapped using NOARL's HIDE-X-BP (III) aboard the USNS *Bartlett*, UCSB's HIDE-X-BP (I) aboard R/V *Seward Johnson* and HBOI's Low Light Auto-Radiometer (LoLAR) on the Johnson-Sea-Link Submersible. This proved to be an extremely powerful sampling protocol and resulted in a very detailed and unique data set. Use of the two bathyphotometers on two different ships permitted both a geographical and a time series analysis of the bioluminescence potential. Comparison of the data sets from the two BPs suggests a higher correlation in time rather than space. In other words, comparison of profiles collected at a given station with HIDE-X-III correlate better with HIDE-X-I profiles taken at a different station on the same day than with the HIDE-X-I profiles taken at the same station 48 h later. (Appendix A)

Measurement and sampling devices used with the Johnson-Sea-Link submersible are shown in Figure 1. Stimulated bioluminescence potential was recorded with the Low Light Auto-Radiometer (LoLAR) mounted on the upper work platform. LoLAR, which was developed during 1990 at HBOI with joint funding from ONR, Oceanic Optics Program and NSF, Ocean Sciences Instrumentation is an underwater irradiance meter which extends the sensitivity of underwater irradiance measurements five orders of magnitude below the current limit of $10^{-3} \mu\text{W}/\text{cm}^2$. For profiles of the water column LoLAR was panned around to measure stimulated bioluminescence from the vertical thruster exhaust. These vertical profiles were then compared to HIDE-X-BP profiles made at the same station. (Appendix B)

Horizontal Transects

EAW Based on HIDE-X and LoLAR profiles, depths of interest were selected for LoLAR/ISIT horizontal transects and submersible collections. Video data for computer image analysis was collected with the ISIT video camera mounted inside the observation sphere and focussed on the transect screen mounted in front of the sphere. The screen was a 1 meter hoop with 1800 μm mesh NITEX screen stretched across it. During horizontal transects bioluminescence was mechanically stimulated from organisms which struck or passed through this screen. During horizontal transects bioluminescence was also mechanically stimulated at the 1800 μm mesh NITEX screen stretched across the end of the stimulation tube. This stimulated bioluminescence potential was recorded by LoLAR to a laptop computer in the

Stimulation Tube

SIT U/W Video Camera

Low Light Auto-Radiometer

**HARBOR BRANCH
JOHNSON-SEA-LINK**



ISIT Video Camera

Transect Screen

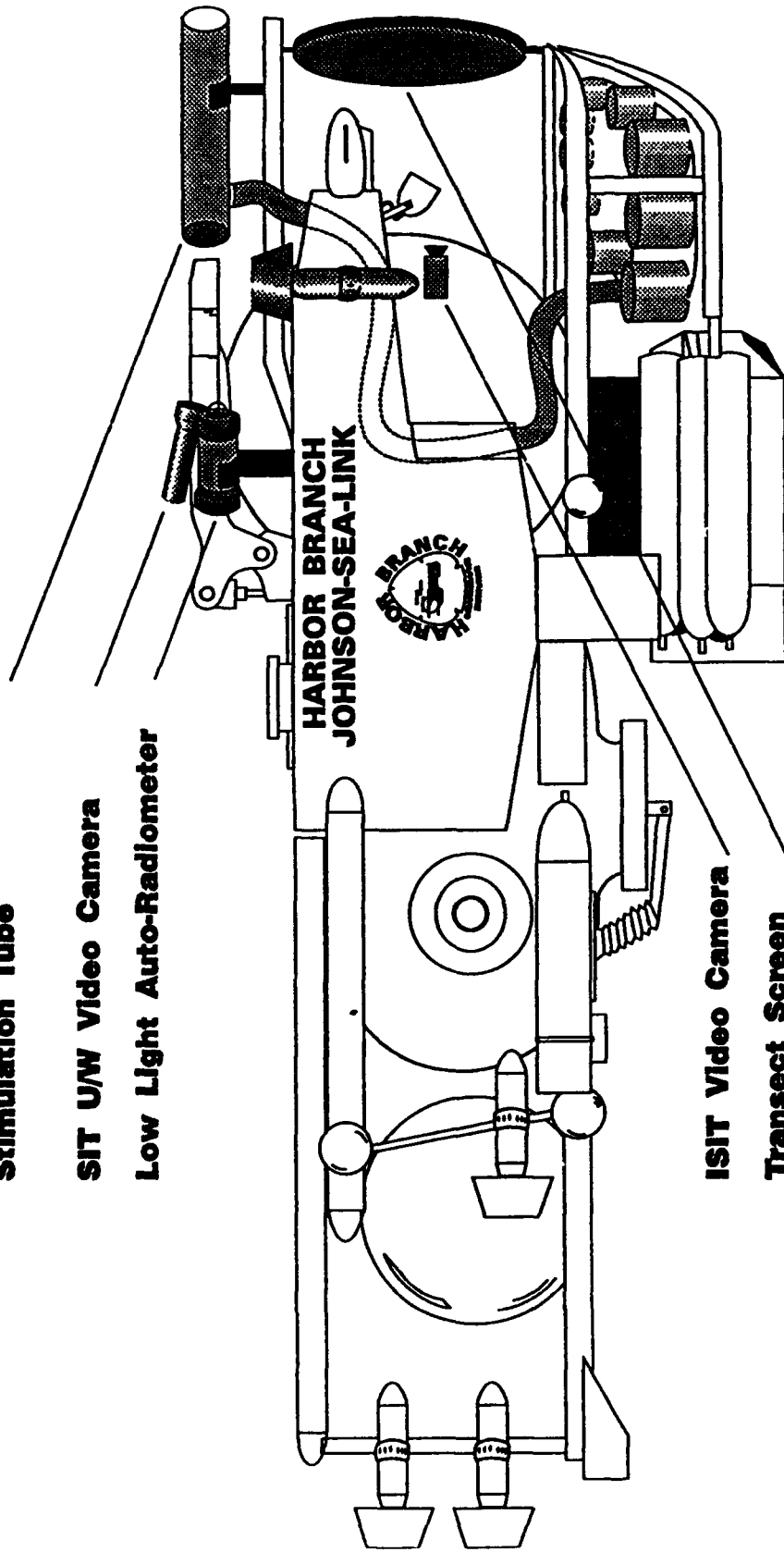


Figure 1

submersible and displayed as a graphics overlay on the ISIT video recording along with time, temperature and depth. Because the volume sampled was relatively small compared to that sampled by the transect screen in front of the observation sphere (5 l/sec compared to 206 l/sec), individual flashes were distinguishable in these PMT recordings. (Appendix C).

The bioluminescent population at the transect depths will be assessed based on computer image analysis of the video transects, FFT analysis of the LoLAR transects and plankton analysis of the quantitative plankton samples collected with the submersibles suction sampler (critter-getter) during each transect. Distributional patterns of these bioluminescent populations will then be correlated with the hydrographical, optical and chemical data collected at each station.

Bioluminescence potential recorded with the LoLAR and HIDE-X-BPs was very intense in surface waters at the southern stations (in excess of 10^{13} p s⁻¹ l⁻¹). A large proportion of the bioluminescence at these stations was attributable to the heterotrophic dinoflagellates *Noctiluca miliaris* and *Protoperidinium* spp. At several of the southern stations *N. miliaris* was found in concentrations up to 1 cell/ml. Ctenophores were also common in surface waters and brilliantly luminescent. In order to construct a light budget for the region, measurements were made from net-captured and submersible-captured specimens. Using LoLAR, measurements were also made *in situ* from individual identified organisms. Laboratory studies of captured specimens included measurements of spectral (OMA and CCD spectrometer), temporal (integrating sphere and CCD spectrometer) and spatial (Mixed Light Imaging System) features of emission parameters. Emission characteristics recorded in the laboratory were used to identify organisms *in situ* based on their bioluminescent responses during the horizontal video transects. One ctenophore in particular deserves mention in this regard, *Euplokamis stationis* (Figure 2). This cydippid was the most spectacularly luminous ctenophore of all those studied as well as being common at all stations. It produced not only repeated comb row flashes of very high intensity but also a long lasting luminous secretion which was released from the oral end of each comb row. These two very different display modes could be produced simultaneously or independently. The unusual nature and exceptional intensity (*in situ* LoLAR measurements measured a photon flux of 1×10^{12} p s⁻¹ at the peak of the flash) of this ctenophore made it easily identifiable during transects based solely on its bioluminescent responses (Figure 3).

During the cruise we made 27 submersible dives (#2929-#2955), 105 HIDE-X-BP profiles, 26 net tows and 6 blue-water scuba collections. A total of 275 specimens were collected by submersible and another 238 by SCUBA.

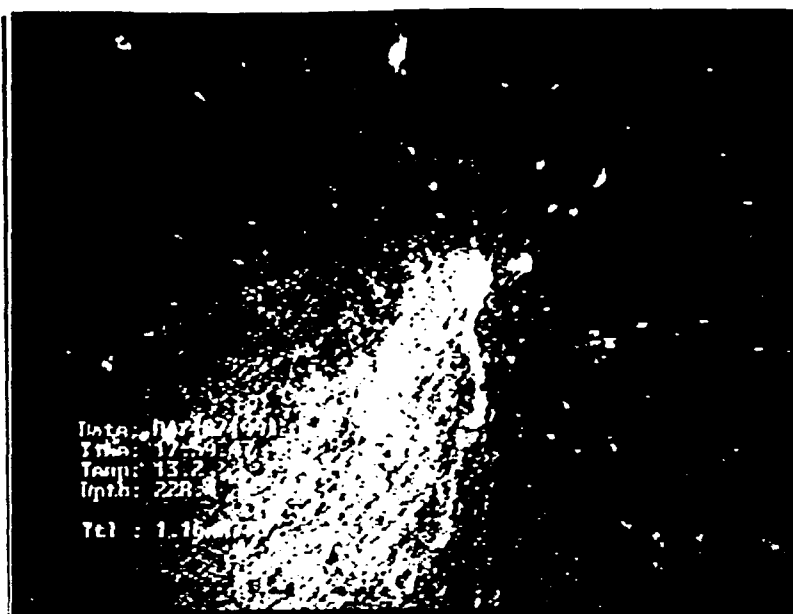


Figure 2 - Video still-frame of bioluminescence display recorded from *Euplokamis stasionis* during transect at 228 m, Station 7 (Dive 2938).

Euplokamis stasionis LoLAR Measurement

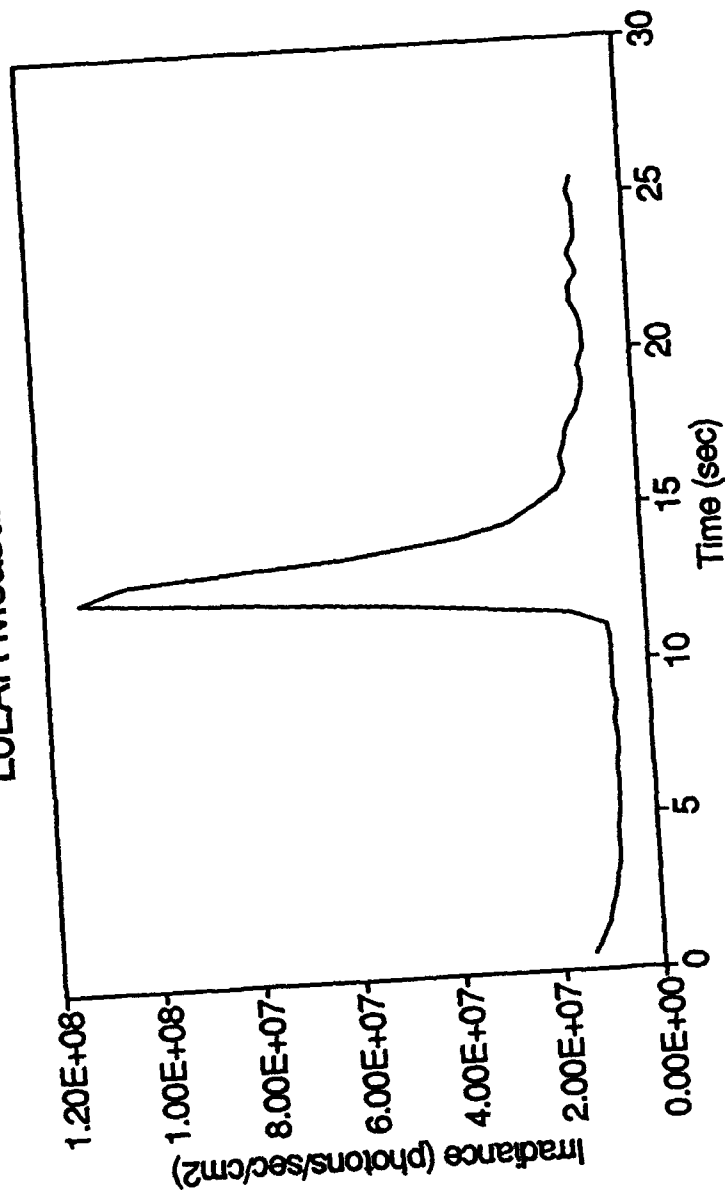


Figure 3 - *In situ* LoLAR recording of stimulated bioluminescence from *Euplokamis stasionis*

Gelatinous zooplankton

Scuba Collections

GRH

Six scuba dives were made at the following locations (Table 1). In every case, the divers were R. Harbison, S. Haddock. Times are given in Greenwich Mean Time, which was two hours ahead of the local time in Spain.

Table 1

Dive No.	Lat.	Long.	Date	Dive Time (GMT)
1894	35 53 N	03 22 W	10 Apr 91	1730-1814
1895	35 44 N	02 49 W	12 Apr 91	1715-1815
1896	35 46 N	03 13 W	14 Apr 91	1610-1705
1897	35 47 N	03 12 W	15 Apr 91	1630-1728
1898	35 46 N	03 15 W	16 Apr 91	1745-1830
1899	36 04 N	02 48 W	17 Apr 91	1530-1600

Table 2 gives a list of the specimens collected (a total of 253). Since our specialty is gelatinous zooplankton, the nature of the collections is skewed. Few specimens of other animals were collected, and those that were could not be identified to species. The data are good, however, for ctenophores, salps, siphonophores and medusae.

Table 2

Specimen No.	Genus, Species	Taxon
1896 12	Sappharina sp.	Copepod
1896 32b	Sappharina sp.	Copepod
1894 01	Beroe forskali	Ctenophore
1894 16b	Beroe forskali	Ctenophore
1898 07	Beroe forskali	Ctenophore
1899 06	Beroe forskali	Ctenophore
1894 05	Beroe ovata	Ctenophore
1894 15a	Beroe ovata	Ctenophore
1894 17	Beroe ovata	Ctenophore
1894 20	Beroe ovata	Ctenophore
1894 25	Beroe ovata	Ctenophore
1894 26	Beroe ovata	Ctenophore

1894 27	Beroe ovata	Ctenophore
1895 02b	Beroe ovata	Ctenophore
1895 07a	Beroe ovata	Ctenophore
1895 09	Beroe ovata	Ctenophore
1895 11a	Beroe ovata	Ctenophore
1895 13a	Beroe ovata	Ctenophore
1895 15	Beroe ovata	Ctenophore
1895 18b	Beroe ovata	Ctenophore
1895 20	Beroe ovata	Ctenophore
1895 22	Beroe ovata	Ctenophore
1895 27b	Beroe ovata	Ctenophore
1895 29	Beroe ovata	Ctenophore
1896 04b	Beroe ovata	Ctenophore
1896 06	Beroe ovata	Ctenophore
1896 07a	Beroe ovata	Ctenophore
1896 08	Beroe ovata	Ctenophore
1896 09a	Beroe ovata	Ctenophore
1896 13	Beroe ovata	Ctenophore
1896 14	Beroe ovata	Ctenophore
1896 24	Beroe ovata	Ctenophore
1896 25	Beroe ovata	Ctenophore
1896 26	Beroe ovata	Ctenophore
1896 29a	Beroe ovata	Ctenophore
1896 31	Beroe ovata	Ctenophore
1897 11	Beroe ovata	Ctenophore
1897 15	Beroe ovata	Ctenophore
1897 21	Beroe ovata	Ctenophore
1897 29	Beroe ovata	Ctenophore
1897 30	Beroe ovata	Ctenophore
1898 02a	Beroe ovata	Ctenophore
1898 20	Beroe ovata	Ctenophore
1899 07b	Beroe ovata	Ctenophore
1899 17	Beroe ovata	Ctenophore
1894 04b	Bolinopsis vitrea	Ctenophore
1894 10	Bolinopsis vitrea	Ctenophore
1894 14	Bolinopsis vitrea	Ctenophore
1894 16a	Bolinopsis vitrea	Ctenophore
1894 21	Bolinopsis vitrea	Ctenophore
1895 01b	Bolinopsis vitrea	Ctenophore
1895 16b	Bolinopsis vitrea	Ctenophore
1895 23a	Bolinopsis vitrea	Ctenophore
1895 24	Bolinopsis vitrea	Ctenophore
1895 25a	Bolinopsis vitrea	Ctenophore
1895 27a	Bolinopsis vitrea	Ctenophore
1895 28a	Bolinopsis vitrea	Ctenophore

1895 28b	<i>Bolinopsis vitrea</i>	Ctenophore
1895 32b	<i>Bolinopsis vitrea</i>	Ctenophore
1896 03	<i>Bolinopsis vitrea</i>	Ctenophore
1896 05b	<i>Bolinopsis vitrea</i>	Ctenophore
1896 21	<i>Bolinopsis vitrea</i>	Ctenophore
1896 22	<i>Bolinopsis</i> sp.	Ctenophore
1896 29b	<i>Bolinopsis vitrea</i>	Ctenophore
1896 32a	<i>Bolinopsis vitrea</i>	Ctenophore
1897 03	<i>Bolinopsis vitrea</i>	Ctenophore
1897 05c	<i>Bolinopsis vitrea</i>	Ctenophore
1897 07	<i>Bolinopsis vitrea</i>	Ctenophore
1897 08a	<i>Bolinopsis vitrea</i>	Ctenophore
1897 12b	<i>Bolinopsis vitrea</i>	Ctenophore
1897 16b	<i>Bolinopsis vitrea</i>	Ctenophore
1897 22b	<i>Bolinopsis vitrea</i>	Ctenophore
1897 23c	<i>Bolinopsis vitrea</i>	Ctenophore
1897 25a	<i>Bolinopsis vitrea</i>	Ctenophore
1897 31	<i>Bolinopsis vitrea</i>	Ctenophore
1897 32	<i>Bolinopsis vitrea</i>	Ctenophore
1897 37	<i>Bolinopsis vitrea</i>	Ctenophore
1898 01	<i>Bolinopsis vitrea</i>	Ctenophore
1898 04b	<i>Bolinopsis vitrea</i>	Ctenophore
1898 06c	<i>Bolinopsis vitrea</i>	Ctenophore
1899 14b	<i>Bolinopsis?</i> sp.	Ctenophore
1895 17b	<i>Eurhamphaea vexilligera</i>	Ctenophore
1894 04c	<i>Haeckelia beehleri</i>	Ctenophore
1894 11	<i>Haeckelia beehleri</i>	Ctenophore
1894 12	<i>Haeckelia beehleri</i>	Ctenophore
1894 13	<i>Haeckelia beehleri</i>	Ctenophore
1894 18	<i>Haeckelia beehleri</i>	Ctenophore
1894 19	<i>Haeckelia beehleri</i>	Ctenophore
1894 22	<i>Haeckelia beehleri</i>	Ctenophore
1896 05a	<i>Haeckelia beehleri</i>	Ctenophore
1897 34	<i>Haeckelia beehleri</i>	Ctenophore
1897 36b	<i>Haeckelia beehleri</i>	Ctenophore
1898 03a	<i>Haeckelia beehleri</i>	Ctenophore
1898 09a	<i>Haeckelia beehleri</i>	Ctenophore
1898 09c	<i>Haeckelia beehleri</i>	Ctenophore
1898 10c	<i>Haeckelia beehleri</i>	Ctenophore
1898 11b	<i>Haeckelia beehleri</i>	Ctenophore
1898 18	<i>Haeckelia beehleri</i>	Ctenophore
1899 09b	<i>Haeckelia beehleri</i>	Ctenophore
1899 12	<i>Haeckelia beehleri</i>	Ctenophore

1897 04c	<i>Haeckelia bimaculata</i>	Ctenophore
1898 03b	<i>Haeckelia bimaculata</i>	Ctenophore
1898 12	<i>Haeckelia bimaculata</i>	Ctenophore
1894 23a	<i>Haeckelia rubra</i>	Ctenophore
1895 21	<i>Haeckelia rubra</i>	Ctenophore
1897 04b	<i>Haeckelia rubra</i>	Ctenophore
1898 05a	<i>Haeckelia rubra</i>	Ctenophore
1898 09b	<i>Haeckelia rubra</i>	Ctenophore
1899 15b	<i>Haeckelia rubra</i>	Ctenophore
1894 08	<i>Leucothea multicornis</i>	Ctenophore
1895 25b	<i>Leucothea multicornis</i>	Ctenophore
1896 02	<i>Leucothea multicornis</i>	Ctenophore
1896 28	<i>Leucothea multicornis</i>	Ctenophore
1895 10	<i>Ocyropsis maculata</i>	Ctenophore
1899 07a	<i>Ocyropsis maculata</i>	Ctenophore
1894 04a	<i>Ocyropsis maculata immaculata</i>	Ctenophore
1897 27	<i>Ocyropsis maculata immaculata</i>	Ctenophore
1898 19	<i>Ocyropsis maculata immaculata</i>	Ctenophore
1898 06e	<i>Ocyropsis maculata immaculata?</i>	Ctenophore
1895 12	<i>Pleurobrachia rhodopis</i>	Ctenophore
1895 30a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1896 17	<i>Pleurobrachia rhodopis</i>	Ctenophore
1896 18	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 10c	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 12a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 14	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 16a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 19a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 22a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 23b	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 26a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 33a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1897 38a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1898 04a	<i>Pleurobrachia rhodopis</i>	Ctenophore
1898 06d	<i>Pleurobrachia rhodopis</i>	Ctenophore
1898 14	<i>Pleurobrachia rhodopis</i>	Ctenophore
1898 16b	<i>Pleurobrachia rhodopis</i>	Ctenophore
1895 01a	Ctenophore n. sp.	Ctenophore
1895 17a	Ctenophore n. sp.	Ctenophore
1895 19b	Ctenophore n. sp.	Ctenophore
1897 04a	Ctenophore n. sp.	Ctenophore

1897 36a	Ctenophore n. sp.	Ctenophore
1898 05b	Ctenophore n. sp.	Ctenophore
1898 11a	Ctenophore n. sp.	Ctenophore
1899 09a	Ctenophore n. sp.	Ctenophore
1899 10	Ctenophore n. sp.	Ctenophore
1899 14a	Ctenophore n. sp.	Ctenophore
1899 18	Ctenophore n. sp.	Ctenophore
1894 23b	Ctenophore n. sp.	Ctenophore
1894 24	Ctenophore n. sp.	Ctenophore
1894 06	Velamen parallelum	Ctenophore
1897 10b	Gennadas sp.	Decapod
1896 11b	Euphausiid sp.	Euphausiid
1899 05	Fish sp.	Fish
1896 32c	Larvacean sp.	Larvacean
1899 04	Larvacean sp.	Larvacean
1895 06	Laodicea undulata	Medusa
1897 05b	Liriope sp.	Medusa
1897 33b	Obelia sp.	Medusa
1895 03	Pandea conica	Medusa
1895 11b	Pandea conica	Medusa
1895 13b	Pandea conica	Medusa
1895 26	Pandea conica	Medusa
1896 04a	Pandea conica	Medusa
1896 20b	Pandea conica	Medusa
1897 06	Pandea conica	Medusa
1897 10a	Pandea conica	Medusa
1897 24	Pandea conica	Medusa
1897 28	Pandea conica	Medusa
1898 06a	Pandea conica	Medusa
1898 16a	Pandea conica	Medusa
1899 01	Pandea conica	Medusa
1899 03	Pandea conica	Medusa
1899 11	Pandea conica	Medusa
1899 13	Pandea conica	Medusa
1899 16	Pandea conica	Medusa
1897 35a	Phialidium sp.	Medusa
1894 15b	Solmaris leucostyla	Narcomedusa
1895 16a	Solmaris leucostyla	Narcomedusa

1895 18a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1895 23b	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 05d	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 08b	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 09b	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 13a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 20a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 23a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 25b	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1898 06b	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1898 09d	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1898 10a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1898 16c	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1898 17	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1899 14c	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1899 15a	<i>Solmaris leucostyla</i>	<i>Narcomedusa</i>
1897 02	<i>Chrysaora hysoscella</i>	<i>Scyphomedusa</i>
1895 31b	<i>Pelagia noctiluca</i>	<i>Scyphomedusa</i>
1897 01	<i>Pelagia noctiluca</i>	<i>Scyphomedusa</i>
1896 01	<i>Rhizostoma pulmo?</i>	<i>Scyphomedusa</i>
1897 20b	<i>Phyllirhoe</i> sp.	<i>Nudibranch</i>
1897 04d	<i>Tomopterid</i> sp.	<i>Polychaete</i>
1895 23c	<i>Worm</i> sp.	<i>Polychaete</i>
1898 02b	<i>Diacria</i> sp.	<i>Pteropod</i>
1895 19a	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1895 32a	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1896 09c	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1896 11a	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1896 23b	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1897 38b	<i>Radiolarian</i> sp.	<i>Radiolarian</i>
1898 13	<i>Salpa fusiformis</i> sol	<i>Salp</i>
1894 02	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1894 03a	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1894 09	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1895 05	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1896 15	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1896 27	<i>Salpa fusiformis</i> sol.	<i>Salp</i>
1899 02	<i>Salpa maxima</i> agg.	<i>Salp</i>
1899 08	<i>Salpa maxima</i> agg.	<i>Salp</i>

1895 02a	Salpa sp. agg.	Salp
1895 07b	Salpa sp. agg.	Salp
1894 03b	Thalia democratica agg.	Salp
1896 07b	Thalia democratica agg.	Salp
1896 19	Thalia democratica agg.	Salp
1896 20a	Thalia democratica agg.	Salp
1896 23a	Thalia democratica agg.	Salp
1896 30	Thalia democratica agg.	Salp
1897 09a	Thalia democratica agg.	Salp
1897 26b	Thalia democratica agg.	Salp
1898 15	Thalia democratica agg.	Salp
1897 05a	Thalia democratica sol.	Salp
1898 08	Hippopodius hippopus	Siphonophore
1897 20c	Muggiaea atlantica	Siphonophore
1897 35c	Muggiaea atlantica	Siphonophore
1895 01c	Nanomia bijuga	Siphonophore
1895 04	Nanomia bijuga	Siphonophore
1895 08	Nanomia bijuga	Siphonophore
1895 14	Nanomia bijuga	Siphonophore
1896 09b	Nanomia bijuga	Siphonophore
1897 05e	Nanomia bijuga	Siphonophore
1897 09c	Nanomia bijuga	Siphonophore
1897 13b	Nanomia bijuga	Siphonophore
1897 16c	Nanomia bijuga	Siphonophore
1897 17	Nanomia bijuga	Siphonophore
1897 18	Nanomia bijuga	Siphonophore
1897 19b	Nanomia bijuga	Siphonophore
1897 23d	Nanomia bijuga	Siphonophore
1897 25c	Nanomia bijuga	Siphonophore
1897 35b	Nanomia bijuga	Siphonophore
1898 10b	Nanomia bijuga	Siphonophore
1896 16	Physophora hydrostatica	Siphonophore
1894 07	Sulculeolaria quadrivalvis	Siphonophore
1897 39	Sulculeolaria quadrivalvis	Siphonophore

Submersible Collections

Of the submersible dives made, 275 individual specimens were collected (Table 3). It should be noted that the diversity of species were remarkably similar for both shallower (scuba) and deeper (submersible) dives. This is in marked contrast with results from the Bahamas. No specimens of ctenophores were collected that had not been previously described, or had not been collected in the Bahamas. The animals named as "cteno sp. nov. 1, 2, and 3" are presently being described by G.R. Harbison.

Table 3

Specimen No.	Genus, Species	Depth of Collection (feet)
Cephalopods		
2929 CG 11	Brachioteuthis? sp.	1450
2940 CG 03	Heteroteuthis sp.	1925
2940 CG 04	Heteroteuthis sp.	1916
2940 CG 05	Heteroteuthis sp.	1898
2940 CG 05	Heteroteuthis sp.	1898
2940 SS 10	Heteroteuthis sp.	1782
2948 CG 02	Heteroteuthis sp.	2706
2944 CG 03	Squid sp.	1041
Chaetognaths		
2938 DS 06b	Chaetognath sp.	1754
2941 SS 14b	Chaetognath sp.	1640
Ctenophores		
2931 CG 06	Bathocyroe fosteri	1238
2931 DS 02	Bathocyroe fosteri	1233
2931 DS 03	Bathocyroe fosteri	1383
2932 DS 01	Bathocyroe fosteri	1220
2935 CG 08	Bathocyroe fosteri	1876
2939 CG 04	Bathocyroe fosteri	1505
2941 CG 01	Bathocyroe fosteri	1292
2941 DS 05	Bathocyroe fosteri	1380
2942 DS 07	Bathocyroe fosteri	1169
2944 DS 01	Bathocyroe fosteri	1247
2946 CG 11	Bathocyroe fosteri	2713

2941 CG 08	Beroe ovata	1590
2944 CG 01	Beroe ovata	1192
2931 CG 11	Beroe sp.	890
2931 DS 04	Beroe sp.	1315
2933 CG 09	Bolinopsis infundibulum	900
2933 CG 10	Bolinopsis infundibulum	900
2933 CG 11	Bolinopsis infundibulum	900
2933 DS 07	Bolinopsis infundibulum	900
2937 DS 04	Bolinopsis infundibulum	2683
2946 DS 08	Bolinopsis infundibulum	2715
2948 CG 01	Bolinopsis infundibulum	2723
2948 CG 07	Bolinopsis infundibulum	1007
2948 DS 08	Bolinopsis infundibulum	2725
2929 CG 01	Bolinopsis infundibulum?	1080
2929 CG 02	Bolinopsis infundibulum?	1080
2929 CG 05	Bolinopsis infundibulum?	984
2929 DS 03	Bolinopsis infundibulum?	1460
2929 DS 07	Bolinopsis infundibulum?	1400
2931 CG 07	Bolinopsis infundibulum?	1192
2937 DS 05	Callianira ficalbi?	1613
2940 DS 05	Cestum veneris	682
2946 CG 09	Cestum veneris	1092
2949 DS 01	Cestum veneris	630
2949 SS 03	Cestum veneris	845
2931 DS 08	Ctenophore sp.	1194
2932 SS 09	Cydippid sp.	1050
2933 DS 05	Cydippid sp.	--
2935 DS 08	Cydippid sp.	2019
2938 SS 05	Cydippid sp.	979
2933 DS 03	Deiopea kaloktenota	805
2944 DS 08	Deiopea kaloktenota	980
2948 CG 09	Deiopea kaloktenota	991
2933 DS 06	Euplokamis sp.	600
2933 DS 02	Euplokamis stationis	900
2935 DS 04	Euplokamis stationis	2085
2937 DS 03	Euplokamis stationis	1764
2938 SS 04	Euplokamis stationis	1014
2943 DS 06	Euplokamis stationis	1852
2944 DS 05	Euplokamis stationis	1159
2946 DS 06	Euplokamis stationis	1080

2946 DS 07	Euplokamis stationis	1896
2948 CG 08	Euplokamis stationis	1005
2948 CG 10	Euplokamis stationis	973
2948 DS 04	Euplokamis stationis	1024
2948 DS 05	Euplokamis stationis	1014
2950 CG 09	Euplokamis stationis	1572
2950 Γ 3 01	Euplokamis stationis	1582
2950 JS 03	Euplokamis stationis	1350
2952 DS 03	Euplokamis stationis	2393
2931 DS 07	Euplokamis stationis?	862
2932 DS 03	Cteno sp. nov. 1	868
2932 DS 08	Cteno sp. nov. 1	838
2942 DS 06	Cteno sp. nov. 1	1210
2944 DS 06	Cteno sp. nov. 1	1165
2950 DS 02	Cteno sp. nov. 1	1508
2950 DS 04	Cteno sp. nov. 1	1281
2950 DS 07	Cteno sp. nov. 1	1359
2943 DS 04	Cteno sp. nov. 1	1618
2937 DS 06	Lampea pancerina	1631
2943 DS 02	Lampea pancerina	1901
2946 CG 04b	Lampea pancerina	2746
2948 DS 07	Cteno sp. nov. 2	2673
2943 DS 01	Cteno sp. nov. 3	2040
2939 CG 07	Cteno sp. nov. 3	2136
2939 CG 08	Cteno sp. nov. 3	2092
2939 CG 09	Cteno sp. nov. 3	1832
2939 CG 12	Cteno sp. nov. 3	1652
2939 DS 02	Cteno sp. nov. 3	2424
2939 DS 03	Cteno sp. nov. 3	2320
2939 DS 04	Cteno sp. nov. 3	2203
2939 DS 08	Cteno sp. nov. 3	2357
2940 CG 02	Cteno sp. nov. 3	1959
2940 DS 03	Cteno sp. nov. 3	1903
2940 DS 08	Cteno sp. nov. 3	1950
2943 CG 12	Cteno sp. nov. 3	1864
2943 CG 12	Cteno sp. nov. 3	1864
2943 DS 08	Cteno sp. nov. 3	1930
2944 CG 07	Cteno sp. nov. 3	2074
2944 DS 04	Cteno sp. nov. 3	2713
2946 DS 02	Cteno sp. nov. 3	2664
2948 DS 03	Cteno sp. nov. 3	2595
2948 DS 06	Cteno sp. nov. 3	2548

2931 SS 05	Pleurobrachia rhodopis	--
2935 DS 03	Thalassocalyce inconstans	2073
2946 DS 01	Thalassocalyce inconstans	2717
Fish		
2944 DS 02	Stomias sp.	--
2935 CG 06	Gempylid sp.	1902
2933 SS 05	Paralepidid sp.	805
Heteropods		
2944 CG 04	Pterotrachea sp.	998
Echinoderms		
2952 CG 02	Holothurian sp.	2376
2952 CG 12	Holothurian sp.	2375
Hyperiid Amphipods		
2950 CG 06	Amphipod sp.	1600
2944 CG 10	Phronima sp.	1737
Larvaceans (Appendicularians)		
2948 DS 02	Larvacean House sp.	2718
Marine Snow		
2938 DS 03	Marine Snow sp.	1754
2940 DS 01	Marine Snow sp.	700
2941 DS 02	Marine Snow sp.	1676
2942 DS 08	Marine Snow sp.	325
2949 DS 07	Marine Snow sp.	30
2929 DS 06	Squid Ink sp.	1430
Medusae		
2929 DS 05	?Solmissus sp.	1406
2931 DS 05	Haliscera conica	1342
2931 DS 06	Haliscera conica	1463
2933 DS 01	Haliscera conica	1097
2935 CG 05	Haliscera conica	1904
2938 DS 06a	Haliscera conica	1754
2938 SS 03	Haliscera conica	1040
2941 CG 10	Haliscera conica	1488
2943 CG 11	Haliscera conica	1940

2944 CG 12	<i>Haliscera conica</i>	1554
2939 DS 05	<i>Haliscera</i> sp.	1616
2931 CG 05	<i>Octophialucium funerarium</i>	1291
2931 CG 02	<i>Paraphyllina</i> sp.	1650
2931 CG 10	<i>Phialidium hemisphericum?</i>	971
2943 CG 04	<i>Ransonia krampi</i>	1638
2932 DS 05	<i>Solmaris</i> sp.	670
2929 CG 12	<i>Solmissus marshalli</i>	1410
2929 DS 04	<i>Solmissus marshalli</i>	1490
2931 CG 04	<i>Solmissus marshalli</i>	1361
2931 CG 09	<i>Solmissus marshalli</i>	1024
2932 DS 02	<i>Solmissus marshalli</i>	944
2932 SS 07	<i>Solmissus marshalli</i>	1103
2932 SS 08	<i>Solmissus marshalli</i>	1103
2933 CG 12	<i>Solmissus marshalli</i>	762
2933 DS 04	<i>Solmissus marshalli</i>	570
2933 DS 08	<i>Solmissus marshalli</i>	907
2935 CG 03	<i>Solmissus marshalli</i>	1917
2941 CG 06	<i>Solmissus marshalli</i>	1685
2941 CG 07	<i>Solmissus marshalli</i>	1658
2941 SS 14a	<i>Solmissus marshalli</i>	1640
2944 CG 02	<i>Solmissus marshalli</i>	1185
2944 CG 09	<i>Solmissus marshalli</i>	1755
2946 CG 02a	<i>Solmissus marshalli</i>	2713
2946 DS 03	<i>Solmissus marshalli</i>	1863
2946 DS 05	<i>Solmissus marshalli</i>	1070
2933 CG 08	<i>Solmissus</i> sp.	951
2934 DS 05	<i>Solmissus</i> sp.	1617
2934 DS 08	<i>Solmissus</i> sp.	1587
2935 CG 09	<i>Solmissus</i> sp.	1869
2935 CG 10	<i>Solmissus</i> sp.	1858
2939 SS 07	<i>Solmissus</i> sp.	1533
2942 DS 04	<i>Solmissus</i> sp.	1600
2946 CG 07	<i>Solmissus</i> sp.	1884
2946 CG 08	<i>Solmissus</i> sp.	1096
2949 SS 02	<i>Solmissus</i> sp.	900
	Pteropods	
2939 SS 08	<i>Cymbulia</i> sp.	1480

2941 DS 07	Cymbulia sp.	1725
2941 DS 08	Cymbulia sp.	1613
2944 CG 08	Cymbulia sp.	1766
Pyrosomes		
2950 DS 08	Pyrosoma sp.	--
Salps		
2946 CG 10	Salpa fusiformis agg.	1095
2933 CG 01	Salpa fusiformis sol.	344
Scyphomedusae		
2931 DS 01	Paraphyllina sp.	1666
2935 CG 11	Paraphyllina sp.	2090
2936 SS 11	Paraphyllina sp.	--
2938 SS 01b	Paraphyllina sp.	1708
2939 CG 06	Paraphyllina sp.	2365
2939 DS 01	Paraphyllina sp.	2537
2946 CG 01	Paraphyllina sp.	2721
2946 CG 02b	Paraphyllina sp.	2713
2946 CG 03	Paraphyllina sp.	2717
2946 CG 04a	Paraphyllina sp.	2746
2948 CG 03	Paraphyllina sp.	2600
2948 DS 01	Paraphyllina sp.	2732
2937 CG 08	Paraphyllina? sp.	2657
Periphylla periphylla		
2934 DS 03	Periphylla periphylla	1735
2934 DS 04	Periphylla periphylla	1752
2934 DS 06	Periphylla periphylla	1713
2935 CG 01	Periphylla periphylla	2007
2935 CG 12	Periphylla periphylla	2062
2936 SS 09	Periphylla periphylla	2160
2936 SS 12	Periphylla periphylla	2110
2937 CG 07	Periphylla periphylla	2667
2937 DS 02	Periphylla periphylla	1750
2938 SS 01a	Periphylla periphylla	1708
2938 SS 02	Periphylla periphylla	1628
2939 CG 05	Periphylla periphylla	2472
2939 CG 10	Periphylla periphylla	1726
2940 CG 01	Periphylla periphylla	1982
2940 DS 06	Periphylla periphylla	1802
2940 DS 07	Periphylla periphylla	1942
2946 CG 05	Periphylla periphylla	2700
2946 CG 06	Periphylla periphylla	2650
2948 CG 04	Periphylla periphylla	2660
2948 CG 05	Periphylla periphylla	2587

2949 SS 01	Periphylla periphylla	2057
2935 CG 04	Periphylla sp.	1910
2935 CG 07	Periphylla sp.	1893
2946 CG 12	Periphylla sp.	2731
Siphonophores		
2950 CG 07	Abylopsis tetragona	1602
2950 CG 08	Abylopsis tetragona	1597
2929 CG 03	Agalma clausi	1048
2929 CG 04	Agalma clausi	1040
2929 DS 01	Agalma clausi	1210
2929 DS 08	Agalma clausi	1130
2931 CG 12	Agalma clausi	854
2938 DS 07	Agalma clausi?	--
2950 DS 06	Agalma elegans	1270
2937 CG 10	Clausophyes ovata	1585
2943 CG 02	Clausophyes ovata	1824
2948 CG 06	Clausophyes ovata	2470
2952 DS 02	Cordagalma cordiformis	2383
2929 DS 02	Forskalia contorta?	1418
2939 CG 03	Forskalia contorta?	1563
2935 DS 06	Forskalia non-leuckarti	1893
2937 CG 09	Forskalia non-leuckarti	1582
2937 DS 01	Forskalia non-leuckarti	1769
2937 DS 07	Forskalia non-leuckarti	1660
2937 DS 08	Forskalia non-leuckarti	1658
2939 CG 01	Forskalia non-leuckarti	1589
2939 CG 11	Forskalia non-leuckarti	1700
2939 DS 06	Forskalia non-leuckarti	1670
2939 DS 07	Forskalia non-leuckarti	1717
2941 DS 03	Forskalia non-leuckarti	1820
2942 DS 03	Forskalia non-leuckarti	1260
2943 CG 01	Forskalia non-leuckarti	1872
2943 DS 03	Forskalia non-leuckarti	1740
2943 DS 05	Forskalia non-leuckarti	1615
2943 DS 07	Forskalia non-leuckarti	1885
2944 CG 11	Forskalia non-leuckarti	1616
2944 DS 03	Forskalia non-leuckarti	1937

2938 DS 02	Forskalia sp.	1166
2931 CG 03	Lensia conoidea	1442
2935 DS 05	Lensia conoidea	1836
2941 CG 02	Lensia conoidea	1280
2941 CG 11	Lensia conoidea	1420
2941 CG 12	Lensia conoidea	1325
2941 DS 06	Lensia conoidea	1735
2943 CG 03	Lensia conoidea	1772
2944 DS 07	Lensia? sp.	1358
2935 DS 01	Lychnagalma utricularia	2060
2935 DS 02	Lychnagalma utricularia	2060
2938 DS 08	Lychnagalma utricularia	--
2941 DS 04	Lychnagalma utricularia	1830
2943 CG 10	Lychnagalma utricularia	1994
2941 DS 01	Physonect "D"?	1615
2940 DS 04	Physonect new	1802
2938 DS 01	Physonect unknown	1182
2936 DS 04	Rhizophysa eysenhardti	2315
2946 DS 04	Rhizophysa eysenhardti	2734
2952 DS 04	Rhizophysa eysenhardti	2375
2940 DS 02	Rhyzophysid sp.	1953
	Trachymedusae	
2935 DS 07	Arctapodema sp.	1897
2938 DS 04	Arctapodema sp.	1770

A comparison of the submersible and scuba collections follows (Table 4):

Table 4

Specimens Collected

Taxon	Submersible	Scuba
Copepods	--	2
Cephalopods	8	--
Ctenophores	97	149
Fish	3	1
Medusae	86	43
Salps	2	21
Siphonophores	53	22

Number of Species Collected

Ctenophores	13	12
Fish	3	1
Medusae	9	9
Salps	1	3
Siphonophores	13	5

The slight change in diversity with depth is quite remarkable when compared with the situation in the Bahamas, where the mesopelagic fauna is considerably more diverse.

Hydromedusae

CEM

Solmissus albescens was the only medusa that could be described as "dominating" any part of the plankton landscape. By day, *Solmissus* typically occurred in a dense layer between about 1000' and 1500'. On many dives, *Solmissus* medusae were as abundant as about 1 m apart within some of this layer. Small numbers of *Solmissus* occurred all the way to the bottom on most day dives. *Solmissus albescens* is known to be a vertical migrator elsewhere in the Mediterranean (see Mills and Goy, 1988, for review), moving up into the upper 100 m during the night. Our night dive observations tented to support that this migration also occurs in the Alboran Sea, although it appears that some animals remain at depth during the night in this location.

Other than *Solmissus albescens*, medusae formed an ever-present, but never dominant part of the macroplankton community at all depths. On most dives, 4-6 species were observed during a submersible traverse of the entire water column. The

most abundant midwater medusae were *Solmissus albescens*, *Haliscera conica*, *Paraphyllina* sp. and *Periphylla periphylla*. All four of these species are probably present throughout the mid-deep water Alboran Sea. All four of these species are also bioluminescent.

In one of the most jelly-rich bands, during Dive JSLI 2950, at 1300 hrs GMT, at about 1600 feet, the balance of predominant gelatinous macroplankton was approximately: 20 *Solmissus* to 4 *Abylopsis* to 1 *Haliscera* to one large chaetognath (genus probably *Sagitta*). For scale in this case, the *Solmissus* were about 1 m apart.

SPECIES LIST: Midwater medusae found off Morocco, Alboran Sea, using Johnson-Sea-Link I submersible.

HYDROMEDUSAE	NAME	ABUNDANCE	DEPTH (FT)
Anthomedusae	<i>Tiaranna rotunda</i>	1	1242
Leptomedusae	<i>Octophialucium funerarium</i>	1	1291
	<i>Phialidium</i> sp.	Few	970-1200
Trachymedusae	<i>Haliscera conica</i>	Common	1000-2000
	<i>Arctapodema</i> sp.	Few	1770-1900
	<i>Ransonia krampi</i>	1	1638
Narcomedusae	<i>Solmissus albescens</i>	Abundant	1000-2800 nite - at surface
	<i>Solmaris ?leucostyla</i>	Few	670
SCYPHOMEDUSAE			
Coronatae	<i>Periphylla periphylla</i>	Common	1800-2800
	<i>Paraphyllina</i> sp.	Common	1350-2800
Semaeostomeae	unidentified species	1	710
Rhizostomes	none		

SPECIES LIST: Medusae collected from the upper 20 m off Morocco and Spanish coasts, Alboran Sea (from SCUBA and plankton net collections).

HYDROMEDUSAE	NAME	ABUNDANCE
Anthomedusae	<i>Pandea conica</i>	Abundant
	<i>Ectopleura dumortieri</i>	
	<i>Lizzia blondina</i>	
Leptomedusae	<i>Obelia</i> sp.	Abundant
	<i>Laodicea undulata</i>	
	<i>Phialidium hemisphaericum</i>	
Trachymedusae	<i>Linope tetraphylla</i>	
	unidentified juveniles	
Narcomedusae	<i>Solmaris leucostyla</i>	Abundant
	<i>Solmundella bitentaculata</i>	
SCYPHOMEDUSAE		
Coronatae	None	
Semaeostomeae	<i>Pelagia noctiluca</i>	Few
	<i>Chrysaora hysoscella?</i>	1
Rhizostomes	<i>Rhizostoma pulmo?</i>	1

Ctenophores

SH

The functions of luminescence among ctenophores are poorly understood, not in the least because the natural history of ctenophores is poorly understood. Animals acquired in excellent shape were used to determine potential predator-prey interactions, and therefore situations in which luminescence may play a role. The genus *Haeckelia*, represented by three species collected during SCUBA dives, included the smallest of the ctenophores we collected, *Haeckelia bimaculata*. Despite its size of only a few millimeters, it appears to be an important component of the bioluminescent community, not only by virtue of its own luminescence, but as a predator on the highly luminescent and abundant medusa *Solmaris leucostyla*.

The plankton of the western Mediterranean proved to remarkably similar to the fauna of the temperate Eastern Pacific. Of the 13 species of ctenophores collected by blue-water dives, only two differed from those which have been found off California employing similar techniques. This finding underscores the value of studies of areas such the Alboran Sea, for while it is a very unique environment, the interactions which occur may be generalized to much larger areas.

Sixty seven specimens of siphonophores, probably belonging to thirteen species, were collected during eighteen of the twenty six scientific dives made by JSL-I during the cruise. Siphonophores are classified according to whether there is present on the stem a float, or pneumatophore, and/or a series of swimming bells (nectosome) at the top of the stem. The calycophoran species do not possess a float and, in general, they are small and fast-swimming. Such species were relatively abundant at depth, but were hard to see from the submersible and difficult to catch, such that only three species were collected. Of these two species were predominant. *Lensia conoidea*, whose fishing posture, with the swimming bells held horizontally, made it easy to identify, was the most abundant. Several specimens of *Abylopsis tetragona* also were collected and proved to have interesting bioluminescence spectra.

The larger physonect species, which possess both a float and a nectosome, proved to be uncommon in comparison with other areas, such as the Bahamas, and low in species diversity. Submersible collection of these species is particularly important as they are fragile organisms, consisting of myriad parts, which are easily destroyed during net collection. Thirty nine physonect specimens, probably representing nine species, were collected, of which four appear to belong to hitherto undescribed species. The most frequently seen and collected species (20 specimens) belonged to the genus *Forskalia*. A second *Forskalia* species also was collected, but neither species could be identified with one of the "recognised" Mediterranean species. These too may prove to be new to science, but the intricacies of the taxonomy of this genus will have to be investigated further.

Two species of the physonect genus *Agalma* were collected. *A. clausi* was mainly found at the more westerly stations (St. 3-4), while the single specimen of *A. elegans* was collected at St. 10. Only one other physonect species, *Lychnagalma utricularia*, was found on more than one occasion. This species was first described, in 1879, from specimens collected in the Straits of Messina. However, no further specimens appear to have been found until we used the JSL submersibles to collect material in the vicinity of the Bahamas, where this species proved to be one of the commonest!

The most interesting siphonophore found during the cruise was the cystonect *Rhizophysa eysenhardti*. These very simple siphonophores, which have a float but no nectosome [although asexual nectophores can be present - see below], can reach great lengths when relaxed. However, the three specimens observed and collected were fairly contracted, but their stems still measured up to 2 metres in length, while

their simple tentacles stretched out below them for at least 10 metres. All three specimens were collected in close proximity to the bottom. These animals, like their close relative the Portuguese Man O'War, have the ability to inflict a powerful and painful sting. They appear to feed mainly on fish, and possibly derive their green coloration from their prey's bile pigment. In addition to the specimens, on one dive a very strange "siphonophore" was observed and collected. It consisted of numerous swimming bells superposing what appeared to be an agglomeration of eggs. On closer examination it proved to be a detached mass of gonodendra of a cystonect siphonophore. Although it is known that the Portuguese Man O'War produces gonodendra, which bear not only the gonophores, containing the sexual products, but also asexual nectophores (swimming bells), and that these gonodendra can be detached as an entity, such a phenomenon probably has never been observed for any of the deep-water cystonect species. It is most likely that this egg mass had been detached from a specimen of *R. eysenhardti* as it too bore a green coloration. Examination of the other specimens of *R. eysenhardti* showed that each individual is unisexual, being either male or female. However, all bore relatively well developed gonodendra on which could be discerned asexual swimming bells at various stages of development.

The SCUBA diving collections also indicated a low species diversity of the larger siphonophores. Only four species were collected, plus an individual nectophore of *Hippopodius hippopus*, which probably had been detached deliberately, as these animals constantly are replacing their bells, and had floated up from a deeper depth. The only common species was the small physonect *Nanomia bijuga*, of which several specimens were collected, one of which had the nudibranch parasite, *Cephalopyge*, attached.

It was a great pity that the weather prevented any diving operations off the coast of Spain as it would have been interesting to know if the populations on the two sides of the Alboran Sea differed in any way.

Species of Siphonophore collected.

Submersible

SCUBA

Sub-order Cystonectae

Rhizophysa eysenhardti

Sub-order Physonectae

Agalma elegans	Nanomia bijuga
Agalma clausi	Physophora hydrostatica
Cordagalma cordiformis	
Lychnagalma utricularia	
Forskalia sp. 1	
Forskalia sp. 2	
Physonect ?sp.nov.1	
Physonect ?sp.nov.2	
Physonect ?sp.nov.3	

Sub-order Calycophorae

Lensia conoidea	Sulculeolaria quadriavvis
Clausophyes ovata	Muggiaea atlantica
Abylopsis tetragona	+ Hippopodius hippopus

Laboratory Measurements of Bioluminescence

Photon Counting and CCD Spectra

MIL

The bioluminescence of single specimens was studied with two laboratory detection systems. A spectrophotometer which uses a charge-couple device (CCD) detector can make repeated "scans" during a luminescent event. Therefore it measures both spectral and temporal emission properties, with a spectral resolution of 3-7 nm, and a temporal resolution of 30 ms. A total of 91 measurements were made with the CCD spectrophotometer.

High resolution measurements of calibrated photon quantum emission and flash kinetics were made in an integrating sphere collector coupled to a photon-counting photomultiplier. This extremely sensitive detector typically measures the intensity of luminescent events with a 10 ms resolution. A total of 455 measurements were made with this system.

Specimens were obtained from JSL submersible operations, blue water SCUBA dives, and plankton net tows. A total of 24 tows were performed to collect material for laboratory experimentation as well as quantitative analysis of species abundance.

On the basis of abundance estimates the heterotrophic dinoflagellates *Noctiluca miliaris* and *Protoperdinium* spp. dominated the southern stations. *N. miliaris* was less abundant at the northern stations, where bioluminescence originated from

dinoflagellates as well as zooplankton such as larvaceans, copepods, and euphausiids.

Laboratory measurements indicated that *N. miliaris* displayed a remarkable capacity for bioluminescence. Bioluminescence is not light inhibited, luminescent reserves are not affected by net collection and handling and many flashes can be produced.

Species	Emission (photons)	Rise (msec)	Max I (phot/s)	Decay (msec)	E-fold (msec)	Duration (msec)	TSL (phot)
<i>Beroe cucumis</i>	5.4E10	95	3.0E11	230	101	325	
<i>Beroe "cuvata"</i>	9.3E11	151	3.4E12	357	140	514	
<i>Beroe forskali</i>	4.1E11	204	1.5E12	421	149	644	
<i>Bolinopsis</i>	2.0E11	157	9.7E11	433	147	621	
Cydippid (RTC)	1.5E9	115	1.3E10	218	80	334	
<i>Euplokamis</i>	8.2E11	79	8.1E12	167	62	355	
<i>Haeckelia beehleri</i>	1.6E10	225	2.7E10	872	291	1193	
<i>Haliscera conica</i>	4.3E9	332	1.5E10	520	165	976	
<i>Intacta</i>	7.1E10	245	1.7E11	942	268	1202	
<i>Lampea pancerina</i>	9.4E10	824	1.9E10	9540	3846	10890	
<i>Leucothea multicornis</i>	7.4E9	221	2.0E10	990	310	1283	
<i>Nephaloctena</i>	2.1E10	102	6.2E10	603	188	723	
<i>Ocyropsis "fusca"</i>	6.4E11	298	2.0E12	1902	389	2243	
<i>Octophialucium</i>	3.4E10	193	1.8E10	6778	921	7081	
<i>Paraphyllina</i>	1.3E10	232	1.7E10	3277	370	3508	
<i>Periphylla periphylla</i>	5.5E11	426	1.9E11	10791	2313	11369	
<i>Phialidium</i>	2.7E10	280	2.4E10	2757	979	3505	
<i>Solmaris</i>	2.8E9	118	1.7E10	455	118	573	
<i>Solmissus marshalli</i>	3.2E10	585	6.9E10	1248	603	1666	
<i>Noctiluca miliaris</i>	8.6E7	44	1.3E9	524	43	568	2.9E9
<i>Protoperidinium</i> 1991	2.5E8	32	5.0E9	206	47	263	7.1E8
<i>Oncaea</i>	9.4E7	33	6.1E8	84	30	120	3.1E9

OMA spectra

SH

Using the Optical Multichannel Analyzer over 100 bioluminescence spectra from several dozen species, many for the first time, were collected. Among the more interesting results was the luminescence of *Abylopsis tetragona*. This midwater siphonophore was extremely common at our later stations and was perhaps the most abundant gelatinous organism at Station 2. Its emission consisted of two distinct and widely separated color bands: one blue at approximately 450 nm, and one narrow blue-green peak centered about 490 nm.

File	Label	ID	Type	Counts	Lam. Max	FWHM
F84.M91	Bacteria G-57		Bact	1403	500.3	95.4
F83.M91	Bacteria G-57		Bact	1199	504.4	94.9
F20.M91	Plate 1 - spot A		Bact	4474	501.8	97.9
F21.M91	Plate 1 - spot B		Bact	7095	482.1	74.7
F25.M91	Plate 3 - spot a		Bact	294	501.3	94.9
F23.M91	Plate 4 - lower left		Bact	936	486.7	81.3
F110.M91	Lucicutia flavicornis	P. Tow	Cope	21	490.0	— BAD
F95.M91	Oncea ?conifera	P. Tow	Cope	228	464.5	90.9
F96.M91	Oncea ?conifera	P. Tow	Cope	225	467.0	91.9
F100.M91	Pleuromamma abdominalis - male	P. Tow	Cope	6063	492.2	78.8
F99.M91	Pleuromamma gracilis - female	P. Tow	Cope	3942	489.2	79.8
F17.M91	Beroe "cuvata"	2931-CG11	Cteno	335	486.7	81.3
F45.M91	Beroe "cuvata"	BW1-27	Cteno	7891	487.7	85.3
F44.M91	Beroe "cuvata"	BW1-27	Cteno	6614	490.7	85.8
F78.M91	Beroe "cuvata"	BW3-25A	Cteno	983	495.3	87.8
F79.M91	Beroe "cuvata"	BW3-25B	Cteno	2154	486.2	88.3
F80.M91	Beroe "cuvata"	BW3-8	Cteno	5450	487.7	86.3
F37.M91	Beroe forskali	BW1-16	Cteno	1524	501.3	89.4
F4.M91	Bolinopsis infundibulum	2929-CG1	Cteno	422	484.2	88.9
F3.M91	Bolinopsis infundibulum	2929-DS7	Cteno	111	489.7	89.9
F51.M91	Bolinopsis infundibulum	BW1-14	Cteno	393	488.7	86.8
F91.M91	Euplokamis stationis	2946-DS6	Cteno	3900	474.6	83.3
F85.M91	Euplokamis stationis	2948-DS5	Cteno	3451	466.5	80.8
F86.M91	Euplokamis stationis	2948-DS5	Cteno	1899	467.0	81.3
F75.M91	Eurhamphea - cydippid	BW2	Cteno	98	497.3	83.3 - Poor
F36.M91	Haeckelia beehleri	BW1-12	Cteno	315	495.8	87.8
F34.M91	Haeckelia beehleri	BW1-19	Cteno	587	498.8	90.4
F92.M91	Haeckelia beehleri	BW5	Cteno	83	492.2	84.8 Poor
F29.M91	Intacta	2932-DS8	Cteno	53	482.1	100.5
F28.M91	Intacta	2932-DS8	Cteno	78	484.7	82.8
F30.M91	Intacta	2932-DS8	Cteno	55	491.2	82.8
F103.M91	Intacta	2950-DS7	Cteno	477	481.1	93.9
F104.M91	Intacta	2950-DS7	Cteno	695	482.1	87.8
F56.M91	Lampea pancerina	2937-DS6	Cteno	9964	475.6	81.3
F81.M91	Leucothea multicornia	BW3-28	Cteno	57	475.6	94.4 - Poor
F49.M91	Leucothea multicornis	BW	Cteno	413	484.7	91.4
F57.M91	Nepheloctena white-tentacle	2939-CG8	Cteno	511	491.2	86.3
F42.M91	Ocyropsis maculata	BW1-4	Cteno	356	492.2	86.3 - better
F39.M91	Ocyropsis maculata	BW1-4	Cteno	646	499.3	89.9 - poor
F69.M91	Red-tentacled cydippid	BW2-19	Cteno	100	498.8	83.3 - poor
F76.M91	Red-tentacled cydippid 2	BW2-17	Cteno	200	496.8	88.9 OK
F6.M91	Noctiluca miliaris	P. Tow	Dino	356	474.1	35.8
F8.M91	Noctiluca miliaris	P. Tow	Dino	194	476.1	36.9
F70.M91	Noctiluca miliaris	P. Tow	Dino	443	478.6	36.9
F72.M91	Protoperdinium sp	P. Tow	Dino	559	480.1	36.9

F73.M91	Protoperidinium sp.	P. Tow	Dino	518	481.6	36.9
F74.M91	Protoperidinium sp.	P. Tow	Dino	555	482.6	37.9
F107.M91	Holothuroid	2952-CG12	Holothur	26	463.0	87.8
F10.M91	Haliscera conica	2931-DS5	Medusa	30	454.9	86.8 For. out 2
F54.M91	Haliscera conica	2939-DS5	Medusa	544	451.3	82.8
F12.M91	Octophialucium	2931-CG5	Medusa	50	489.2	71.7
F90.M91	Paraphyllina ransonii	2948-DS1	Medusa	25	480.0	— TERE 1513
F15.M91	Phialidium ?hemisphericum	2931-CG10	Medusa	145	503.9	37.4
F16.M91	Phialidium ?hemisphericum	2931-CG10	Medusa	82	505.4	40.9
F68.M91	Solmissus	2940-DS4	Medusa	1669	480.1	76.2
F66.M91	Solmissus	2942-DS4	Medusa	14946	480.1	75.7
F101.M91	Pyrosome	2950-DS8	Salp	858	484.7	106.5
F114.M91	Abylopsis tetragona	2953-CG3A	Siph	1034	489.2	61.1
F118.M91	Abylopsis tetragona - ant.	2953-CG3A2	Siph	228	489.7	103
F125.M91	Abylopsis tetragona - ant.	2955-CG9A	Siph	453	488.7	104
F115.M91	Abylopsis tetragona - post.	2953-CG3	Siph	382	488.2	96.9
F124.M91	Abylopsis tetragona - post.	2955-CG9A	Siph	1266	489.7	55
F62.M91	Heteroteuthis	2940-SS10	Squid	5043	484.2	60.6
F60.M91	Heteroteuthis body glow		Squid	3185	481.1	54
F67.M91	Heteroteuthis secretion	2940	Squid	320	502.3	101
F89.M91	Edie's phosphor			3302	451.9	58.1

The objectives of this project, within the overall programme, were to establish the specific sites and modes of expression of the bioluminescence of the midwater gelatinous fauna. The isothermal nature of the Alboran Sea water column, and the capture and recovery capabilities of the Johnson Sea Link provided specimens in unprecedented physiological condition. Experimental stimulation of animals *in situ* provided ideal indications of the "normal" nature of the responses later recorded in the laboratory. The imaging system employed had previously been tested at sea in 1990 in the Eastern Atlantic and the Bahamas, and has been developed at Harbor Branch by Dr E.A.Widder, with whom this investigation was undertaken.

The three groups on which most of the studies focussed were the medusae the ctenophores and the siphonophores. Additional observations were made on a number of other organisms, particularly the squid *Heteroteuthis dispar*. The medusae most frequently observed from the submersible were species of *Periphylla*, *Paraphyllina*, *Solmissus* and *Haliscera*. All four are bioluminescent but differ substantially in the way it is expressed. *Haliscera* is small, fast moving and completely transparent. It produces rapid propagated waves of light (from point sources) which spread over the aboral surface and round the umbrellar margin. *Solmissus* (the single most abundant medusa) is also transparent and brightly luminescent from the lateral umbrellar margin, the velum and down the tentacles. Propagated responses were not usually observed but could occasionally be elicited in the laboratory. The bioluminescence of the small pigmented species *Paraphyllina* was in marked contrast, for it luminesced only from specific sites associated with the lappets and the tentacle bases. The most varied and extensive of luminescent displays were obtained from *Periphylla*. Responses propagated round the umbrella, round each lappet and along the coronal groove, either separately or in concert. Scintillating mucus particles were also emitted. The Mediterranean specimens differed considerably both in their sensitivity and responses from those previously studied in Bahamian waters. They were far less responsive, both *in situ* and in the laboratory, and the aboral bell never contributed significantly to the bioluminescent responses. Nevertheless one specimen developed a "frenzy" of multiple propagated waves when stimulated mechanically. The very small (2-3 mm) medusa *Solmaris leucostyla* produced bioluminescent responses similar to those of *Solmissus*, and because of its numbers must be a significant contributor to the luminescence in near-surface waters. Other luminous medusae examined included

species of *Octophialucium*, *Phialidium*, *Arctopodema* and *Pelagia*.

The responses of the ctenophores were similar to those of animals previously encountered in Bahamian waters, with most of the 10 or so species examined having bright propagated bioluminescence down each comb row. Only *Deiopea* sp. failed to respond to stimulation. *Ocyropsis* proved to be strongly inhibited by illumination (like *Cestum*, noted in 1989). *Nepheloctena* was common at several stations and produced particularly bright comb row flashes. *Euplokamis* was the most spectacularly luminous ctenophore, as well as being common at all stations. It produced not only repeated comb row flashes of high intensity but also a luminous secretion from the oral end of each comb row. This could be produced independently of the comb row flashes. This characteristic response rendered *Euplokamis* easily identifiable in video transects of bioluminescence.

Nine genera of siphonophores were studied and there proved to be a marked distinction between those whose luminescence was localized at specific sites (*Forskalia*, *Clausophyes*, *Nanomia*) and those in which the whole epithelial surface of the nectophores and/or bracts is luminous (*Lensia*, *Abylopsis*, *Agalma*, *Muggiaea*). Only *Lychnagalma* and *Sulculeolaria* proved not to be luminous.

Additional observations were made on 9 specimens of the bioluminescent squid *Heteroteuthis*, and provided new insights into the control and use of the modified bacterial light organ present in the mantle cavity.

Large numbers of a swimming holothurian were seen at station 10, and this species (*Irpa ludwigi*) proved to be brightly luminous over the whole body surface, and particularly from the dorsal papillae.

It is clear that the widespread bioluminescent capabilities and local abundance of the gelatinous midwater fauna of the Alboran Sea will ensure that it will provide a major contribution to the bioluminescence of these waters, particularly at depths below the dinoflagellate-dominated surface waters. The characteristic distributions and kinetics of the bioluminescent responses that have been recorded already make it possible to identify some of the species *in situ* solely by their bioluminescent responses.

HIDEX PROFILE LOG MEDITERRANEAN APRIL 6-24 1991

File Name	Date	Time	Station	Comments
0001.pro	06-Apr-91	(14:49)	3	Std Profile
0002.pro	06-Apr-91	(15:01)	3	Std Profile
0003.pro	07-Apr-91	(19:28)	3	Std Profile
0004.pro	07-Apr-91	(19:57)	3	Std Profile
0005.pro	07-Apr-91	19:31	4	Std Profile
0005.msp	07-Apr-91	20:15	4	Pump Test @ 200M 4-28L/S
0006.pro	07-Apr-91	20:30	4	Std Profile
0006.msp	07-Apr-91	20:39	4	Pump Test @ 5M 4-28L/S
0007.pro	08-Apr-91	01:56	4	Std Profile
0008.pro	08-Apr-91	02:14	4	Std Profile
0009.pro	08-Apr-91	19:35	5	Std Profile
0010.pro	08-Apr-91	19:52	5	Std Profile
0011.pro	08-Apr-91	21:35	5	Std Profile
0012.pro	08-Apr-91	21:50	5	Std Profile
0013.pro	09-Apr-91	01:40	5	Std Profile
0014.pro	09-Apr-91	01:47	5	Profile 7.5M -> 55M
0015.pmp	09-Apr-91	02:03	5	Sample Pump @ 55M 16L/S
0016.msp	09-Apr-91	02:22	5	Pump Test @ 55M 4-28L/S
0017.pmp	09-Apr-91	02:39	5	Sample Pump @ 55M 28L/S
0018.pro	09-Apr-91	19:36	6	Std Profile
0019.pro	09-Apr-91	20:12	6	Std Profile
0020.pro	10-Apr-91	01:00	6	Std Profile
0021.pro	10-Apr-91	01:20	6	Std Profile
0022.pro	10-Apr-91	19:04	7	Dusk Profile Series
0023.pro	10-Apr-91	19:14	7	Dusk Profile Series
0024.pro	10-Apr-91	19:23	7	Dusk Profile Series
0025.pro	10-Apr-91	19:30	7	Dusk Profile Series
0026.pro	10-Apr-91	19:36	7	Dusk Profile Series
0027.pro	10-Apr-91	19:41	7	Dusk Profile Series
0028.pro	10-Apr-91	19:49	7	Dusk Profile Series
0029.pro	10-Apr-91	19:53	7	Dusk Profile Series
0030.pro	11-Apr-91	00:44	7	Std Profile
0031.pro	11-Apr-91	00:55	7	Std Profile
0032.pro	11-Apr-91	19:47	7	
0033.pro	11-Apr-91	19:46	8	Std Profile
0034.pro	11-Apr-91	19:58	8	Std Profile
0035.pro	12-Apr-91	19:10	9	Dusk Profile Series
0036.pro	12-Apr-91	19:20	9	Dusk Profile Series
0037.pro	12-Apr-91	19:25	9	Dusk Profile Series
0038.pro	12-Apr-91	19:31	9	Dusk Profile Series
0039.pro	12-Apr-91	19:36	9	Dusk Profile Series
0040.pro	12-Apr-91	19:41	9	Dusk Profile Series
0041.pro	12-Apr-91	19:47	9	Dusk Profile Series

Conclusions

Bioluminescence potential in the Western Alboran Sea in April '91 was primarily due to a mixture of large numbers of dinoflagellates and small zooplankton. Although gelatinous zooplankton were responsible for the most intense individual bioluminescent displays the very high bioluminescence potential of the region was a consequence of the exceptional abundance of a large variety of non-gelatinous sources and could not be attributed to the extreme intensity of any one emitter.

Acknowledgements

We are indebted to Capt. Dan Schwartz and his crew and to Don Liberatore and the sub crew for a safe and very successful cruise.

This investigation was supported by Grant N00014-90-J1819 from the Office of Naval Research, Grant N00014-91-C6007 from the Naval Oceanographic and Atmospheric Research Laboratory and a grant from the Atlantic Foundation.

Appendix A - HIDEX-BP Profiles

File Name	Date	Time	Station	Comments
0042.pro	12-Apr-91	19:53	9	Dusk Profile Series
0043.pro	12-Apr-91	19:57	9	Dusk Profile Series
0044.pro	12-Apr-91	20:00	9	Dusk Profile Series
0045.pro	13-Apr-91	00:59	9	Std Profile
0046.pro	13-Apr-91	01:21	9	Std Profile
0046.pmp	13-Apr-91		9	Sample Pump @ 14M 16L/S
0047.pmp	13-Apr-91		9	Sample Pump @ 9M 16L/S
0048.pmp	12-Apr-91	18:08	9	Sample Pump @ 2M 16L/S
0049.pro	14-Apr-91	18:19	12	Std Profile
0050.pro	14-Apr-91	18:22	12	Std Profile
0051.pro	14-Apr-91	22:42	12	Std Profile
0052.pro	14-Apr-91	22:55	12	Std Profile
0053.pro	14-Apr-91	23:04	12	Std Profile
0054.msp	14-Apr-91	23:22	12	Pump Test @ 37M 4-28L/S
0055.msp	14-Apr-91	23:35	12	Pump Test @ 22M 4-28L/S
0056.msp	14-Apr-91	23:36	12	Pump Test @ 5M 4-28L/S
0057.pmp	15-Apr-91	00:09	12	Sample Pump @ 21M 16L/S
0058.pmp	15-Apr-91	00:22	12	Sample Pump @ 15M 16L/S
0059.pmp	15-Apr-91	00:38	12	Sample Pump @ 09M 16L/S
0060.pro	15-Apr-91	18:23	12	Std Profile
0061.pro	15-Apr-91	18:47	12	Std Profile
0062.pro	15-Apr-91	23:35	12	Std Profile
0063.pro	15-Apr-91	23:49	12	Std Profile
0064.msp	16-Apr-91	00:01	12	Pump Test @ 0M 4-28L/S XX
0065.msp	16-Apr-91	00:17	12	Pump Test @ 0M 4-28L/S
0066.pro	16-Apr-91	19:56	12	Std Profile
0067.pro	16-Apr-91	20:06	12	Std Profile
0068.pro	17-Apr-91	02:03	12	Std Profile
0069.pro	17-Apr-91	02:03	12	Std Profile
0070.pro	17-Apr-91	20:08	10	Std Profile
0071.pro	17-Apr-91	20:17	10	Std Profile
0072.pro	18-Apr-91	00:49	10	Std Profile
0073.pro	18-Apr-91	01:00	10	Std Profile
0074.pro	19-Apr-91	19:07	14	Std Profile
0075.pro	19-Apr-91	19:18	14	Std Profile
0076.pro	19-Apr-91	19:27	14	Std Profile
0077.pro	19-Apr-91	19:42	14	Std Profile
0078.pro	20-Apr-91	23:05	15	Std Profile
0079.pro	20-Apr-91	23:16	15	Std Profile
0080.pro	21-Apr-91	20:55	16	Std Profile
0081.pro	21-Apr-91	21:06	16	Std Profile
0082.pro	21-Apr-91	21:15	16	msp abort
0083.pro	21-Apr-91	21:27	16	Pump Test @ 18M 4-28L/S
0084.pro	21-Apr-91	21:40	16	Pump Test @ 50M 4-28L/S

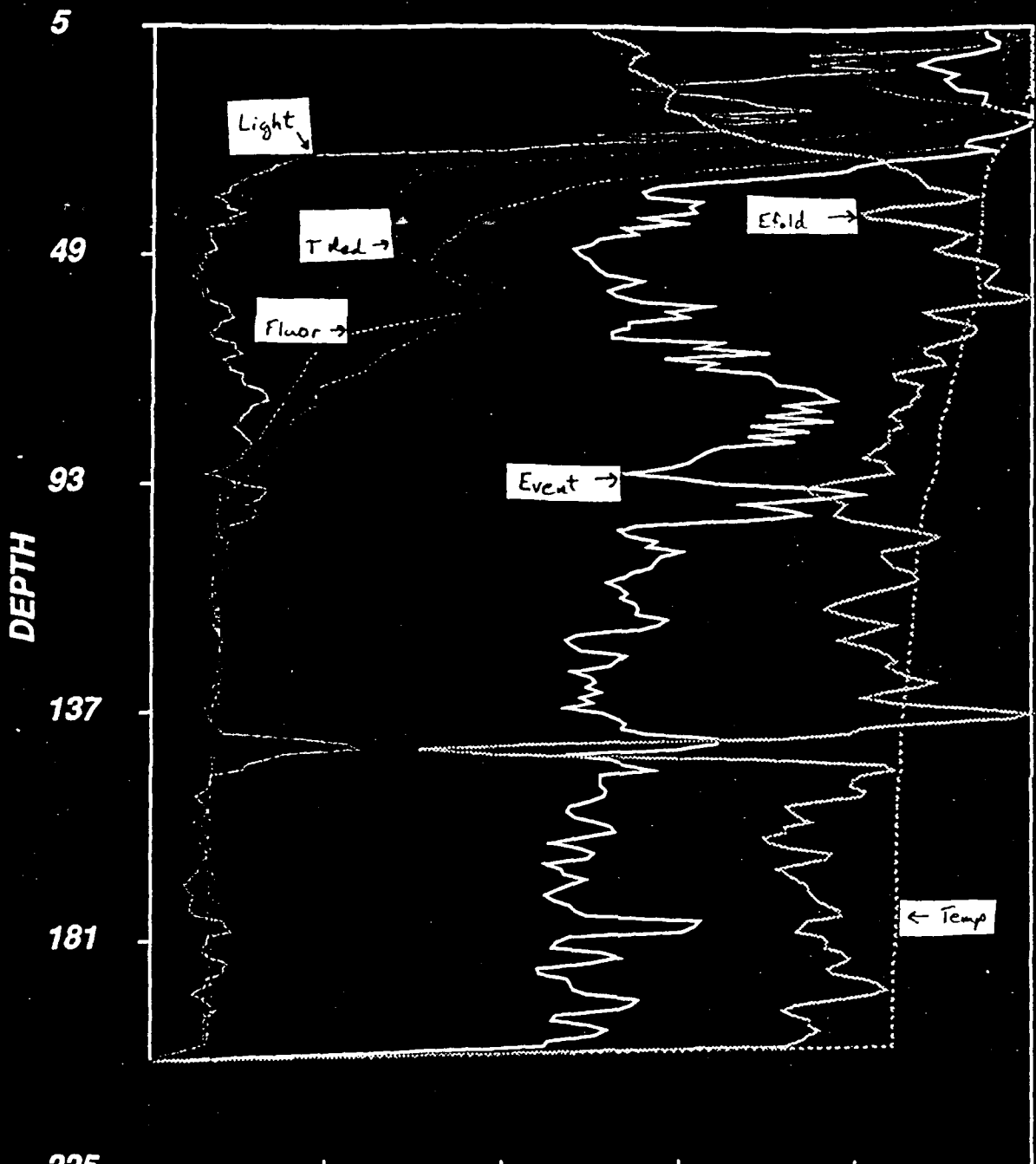
File Name	Date	Time	Station	Comments
0085.pro	21-Apr-91	21:49	16	Pump Test @ 50M 4-28L/S
0086.pro	21-Apr-91	21:58	16	Pump Test @ 50M 4-28L/S
0087.pro	21-Apr-91	22:10	16	Pump Test @ 18M 4-28L/S
0088.pro	21-Apr-91	22:22	16	Std Profile
0089.pro	21-Apr-91	22:34	16	Std Profile
0090.pro	22-Apr-91	20:41	17	Std Profile
0091.pro	22-Apr-91	20:52	17	Std Profile
0092.pro	22-Apr-91	22:18	17	Std Profile
0093.pro	22-Apr-91	22:30	17	Std Profile
0094.pro	23-Apr-91	00:09	17	Std Profile
0095.pro	23-Apr-91	00:10	17	Std Profile
0096.pro	23-Apr-91	00:34	17	Pump Test @ 50M 4-28L/S
0097.pro	23-Apr-91	00:43	17	Pump Test @ 50M 4-28L/S
0098.pro	23-Apr-91	00:56	17	Pump Test @ 12M 4-28L/S
0099.pro	23-Apr-91	01:04	17	Pump Test @ 12M 4-28L/S
0100.pro	23-Apr-91	20:00	2	Std Profile
0101.pro	23-Apr-91	20:10	2	Std Profile
0102.pro	24-Apr-91	01:04	2	Std Profile
0103.pro	24-Apr-91	01:14	2	Std Profile
0104.pro	24-Apr-91	03:46	1	Std Profile
0105.pro	24-Apr-91	03:58	1	Std Profile

Time : 23:04.59
 Date : 04/20/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

PROF ST 15
 0078.pro



225	1.72e-11	3.44e-11	5.17e-11	6.89e-11	8.61e-11
Event 0	1.06	2.11	3.17	4.22	5.28
Efold 0	0.137	0.273	0.41	0.547	0.684
Temp 0	3.2	6.4	9.59	12.8	16

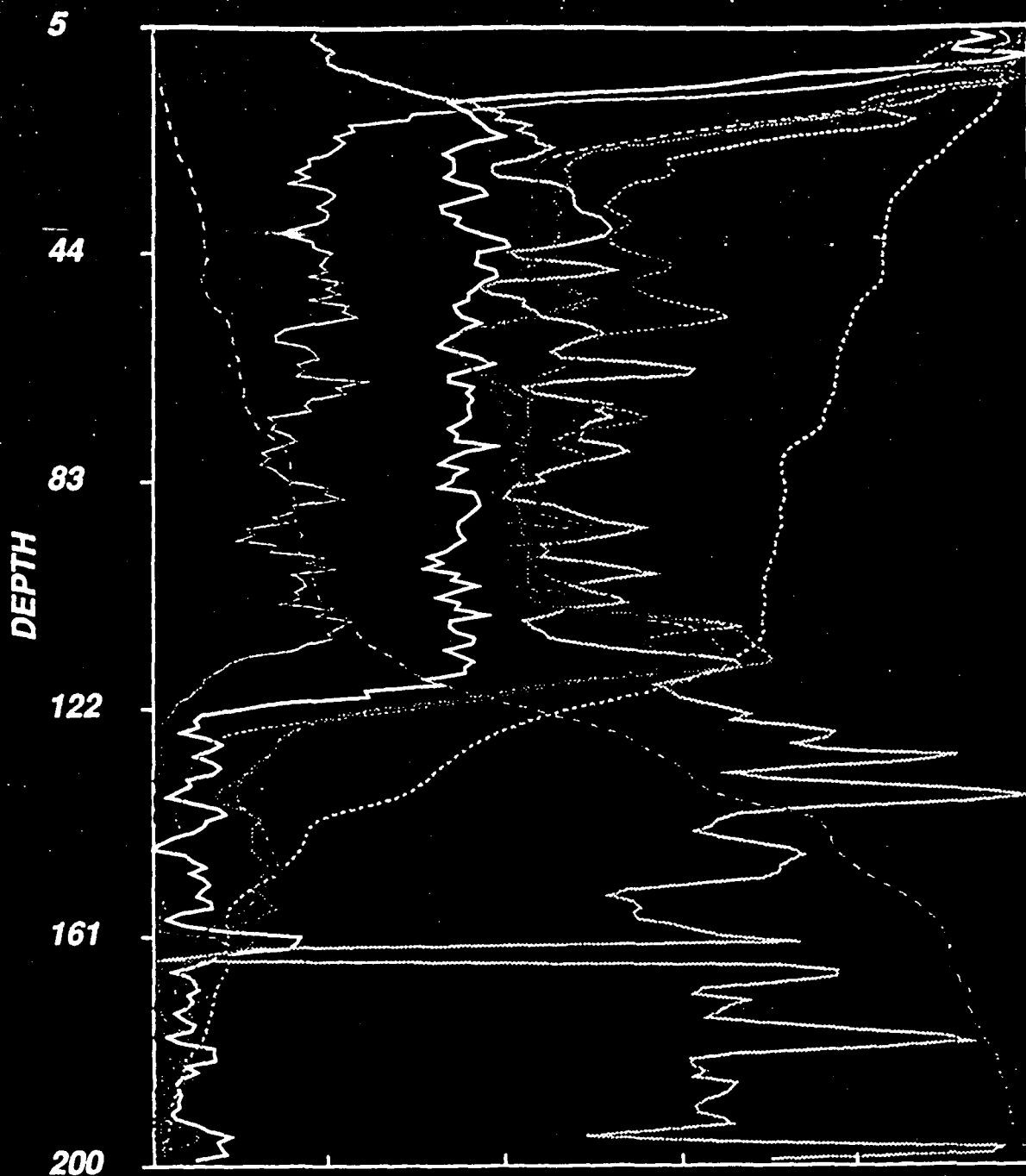
100	3.07	6.14	9.21	12.28	15.35
50	0.137	0.273	0.41	0.547	0.684

Time: 03:46.20
Date: 04/24/1991
Cruise: MED

Longitude: 000 000 00
Latitude: 000 000 00

Type:
Data File:

PROF ST 1
0104.pro



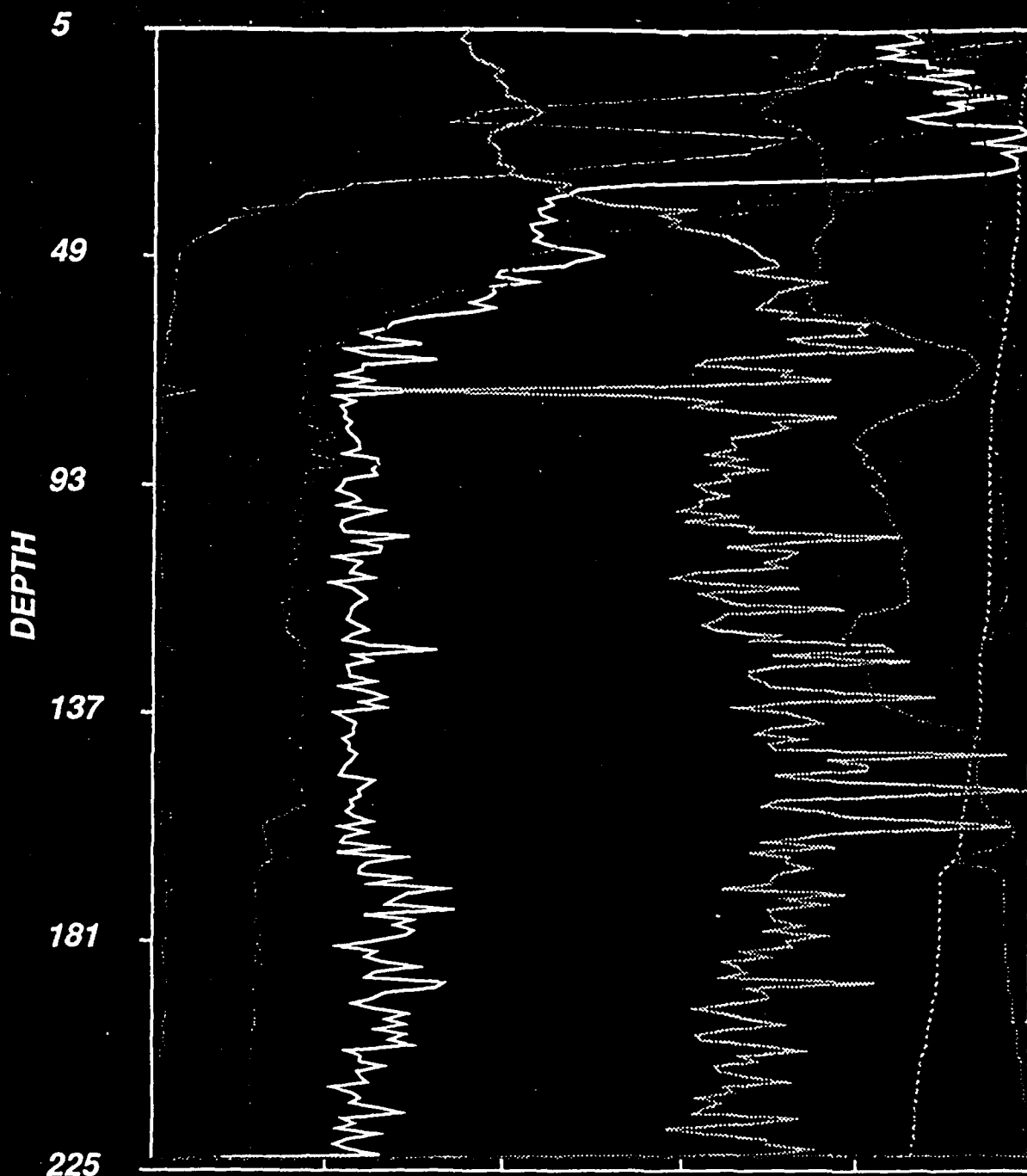
	2.35	3.77	5.18	6.6	8.01	9.42
Event	2.35	3.77	5.18	6.6	8.01	9.42
Efold	0.378	0.435	0.493	0.551	0.608	0.666
Temp	13.5	14	14.4	14.8	15.3	15.7
Chlor	38.0	38.5	37.5	37.5	38.4	38.7
Fluor	1.27	1.75	2.25	2.78	3.21	3.67
Chlor	0.0001	0.0009	0.0027	0.0062	0.0193	0.0284
T Blue	0.91	0.354	0.398	0.442	0.486	

Time : 19:57.11
 Date : 04/06/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

Sis prof
 0004.pro



Event	0	2.21	4.41	6.62	8.82	11
Efold	0	0.156	0.312	0.467	0.623	0.779
Temp	0	3.12	6.24	9.36	12.5	15.6

11500
 100000

14.7

27.2

44

68.7

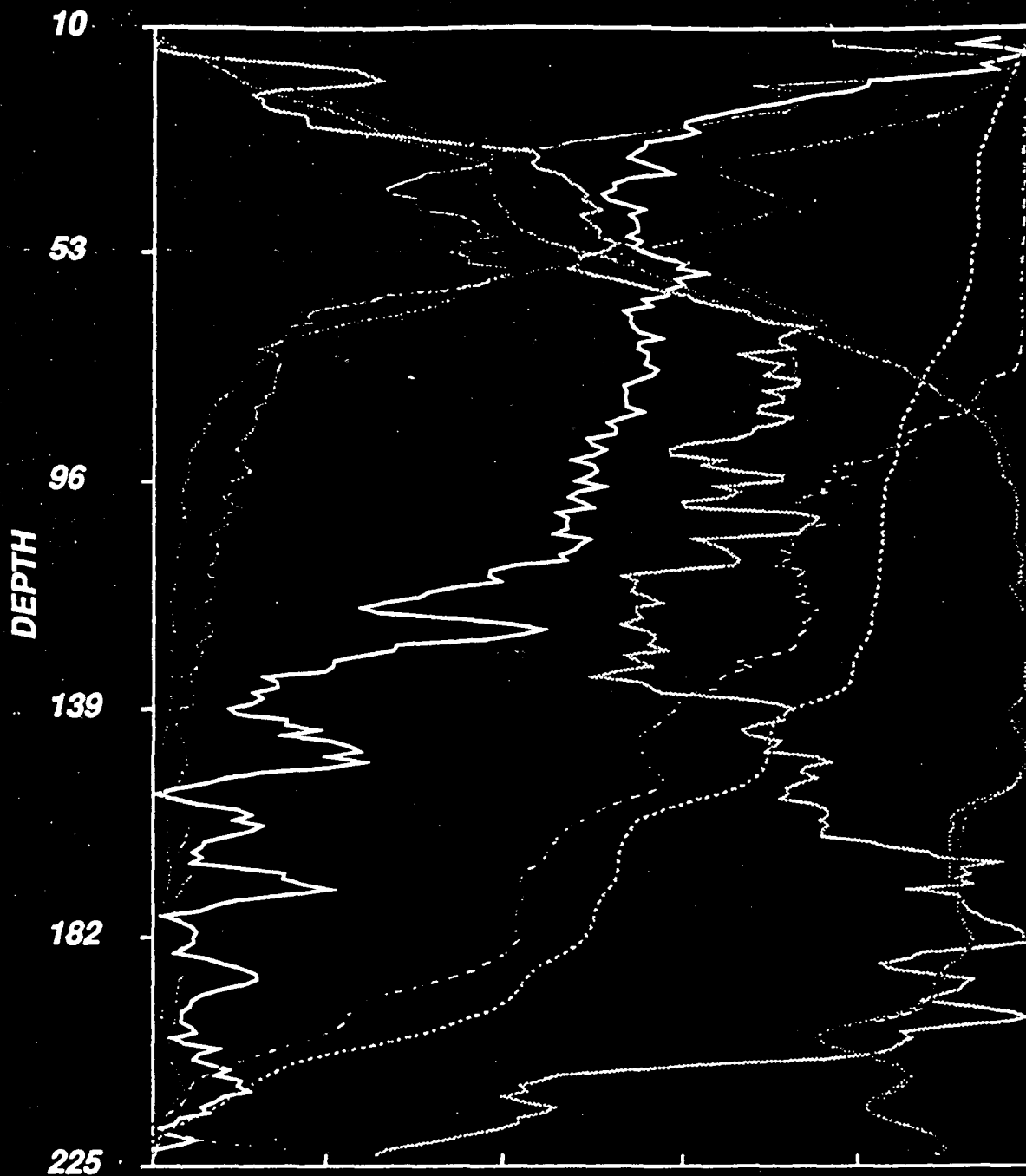
30.1
 HDEX Software Version 3.0
 © Marine Bioluminescence Group, 1991

Time : 01:56.21
 Date : 04/07/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

PROFILE
 0007.pro



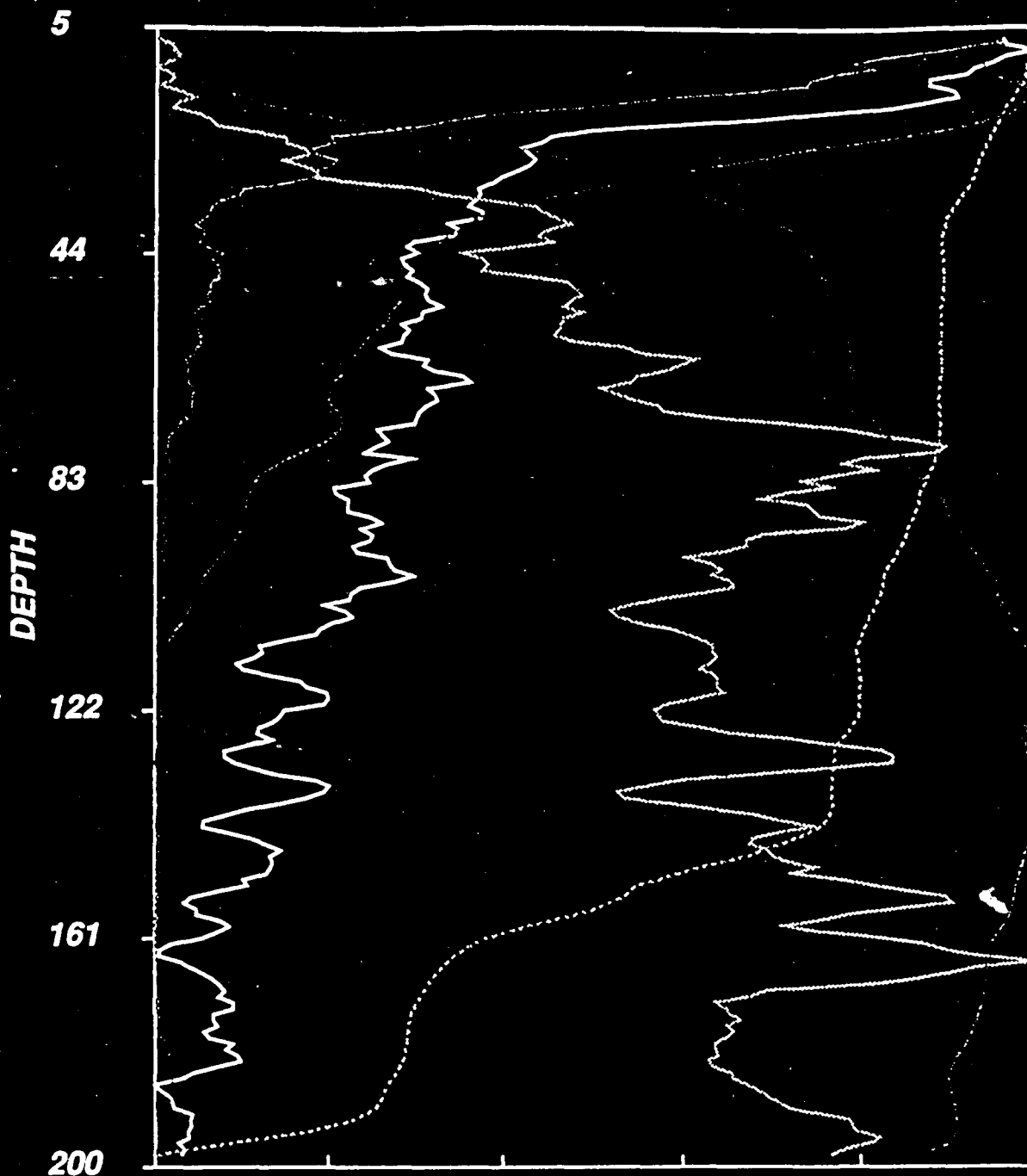
Event	2.86	3.6	4.34	5.07	5.81	6.55
Efold	0.385	0.434	0.483	0.533	0.582	0.631
Temp	13.4	13.8	14.3	14.7	15.1	15.6
Sal	35.3	35.3	35.3	35.3	35.3	35.3
Chl	0.0	0.0	0.0	0.0	0.0	0.0
T Blue	55.4	59.5	63.6	67.8	71.9	

Time : 21:35.44
 Date : 04/07/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

PROFILE
 0011.pro



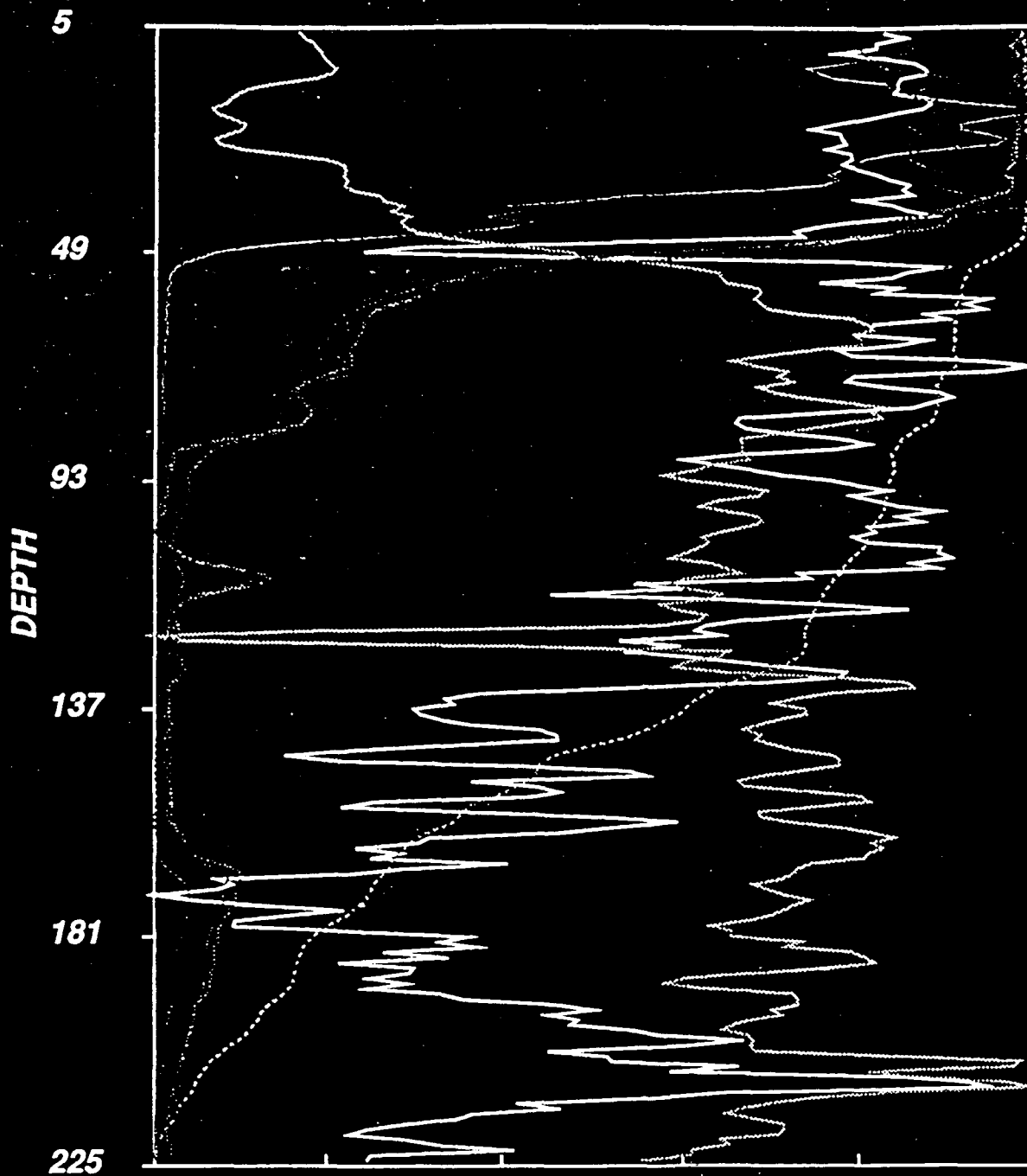
	1.29	2.05	2.81	3.56	4.32	5.08
Event	1.29	2.05	2.81	3.56	4.32	5.08
Efold	0.348	0.414	0.48	0.546	0.612	0.678
Temp	13.7	14	14.4	14.8	15.1	15.5

Time : 01:00.39
 Date : 04/10/1991d
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

PROFILE 0020.pro



Event	2.62	3.12	3.62	4.11	4.61	5.1
Efold	0.256	0.334	0.411	0.488	0.565	0.643
Temp	13.4	13.8	14.2	14.7	15.1	15.5

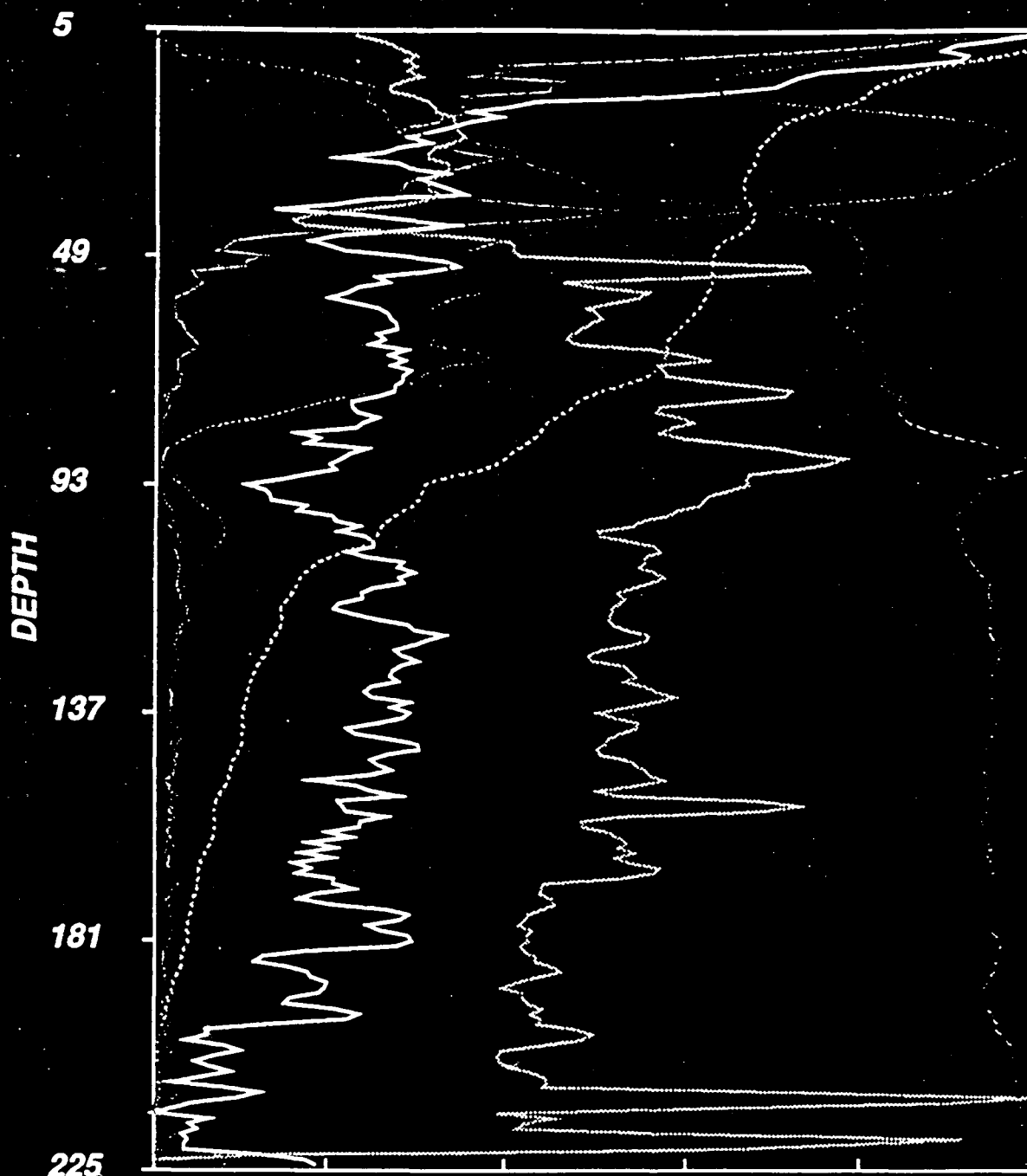
Event	2.62	3.12	3.62	4.11	4.61	5.1
Efold	0.256	0.334	0.411	0.488	0.565	0.643
Temp	13.4	13.8	14.2	14.7	15.1	15.5

Time : 00:44.37
 Date : 04/11/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

prof_ST7
 0030.pro



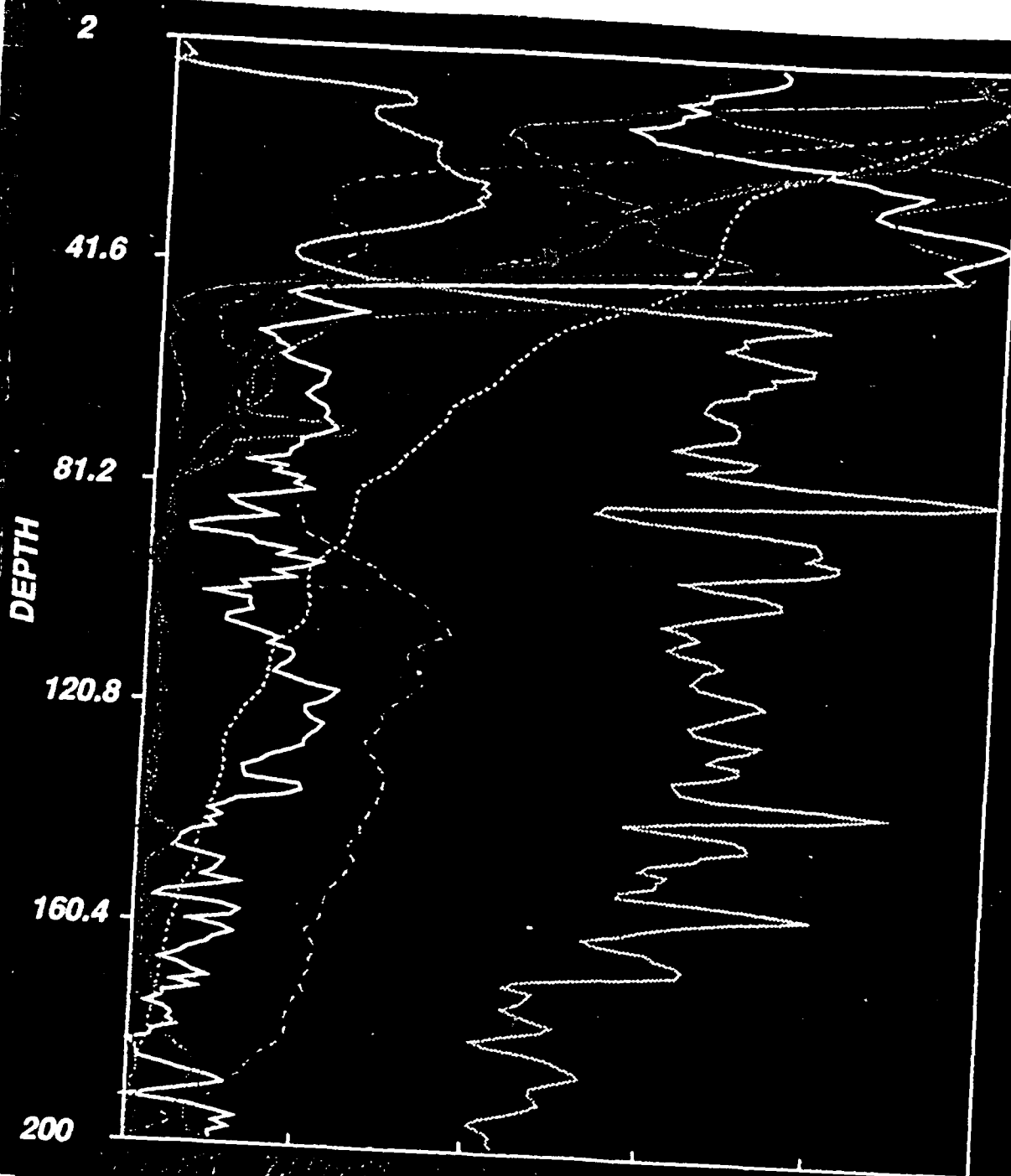
Event	3.08	4.41	5.73	7.06	8.38	9.71
Efold	0.263	0.362	0.461	0.559	0.658	0.757
Temp	13.4	13.9	14.4	14.8	15.3	15.8

Time : 22:42.47
 Date : 04/14/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

Prof ST 12
 0051.pro



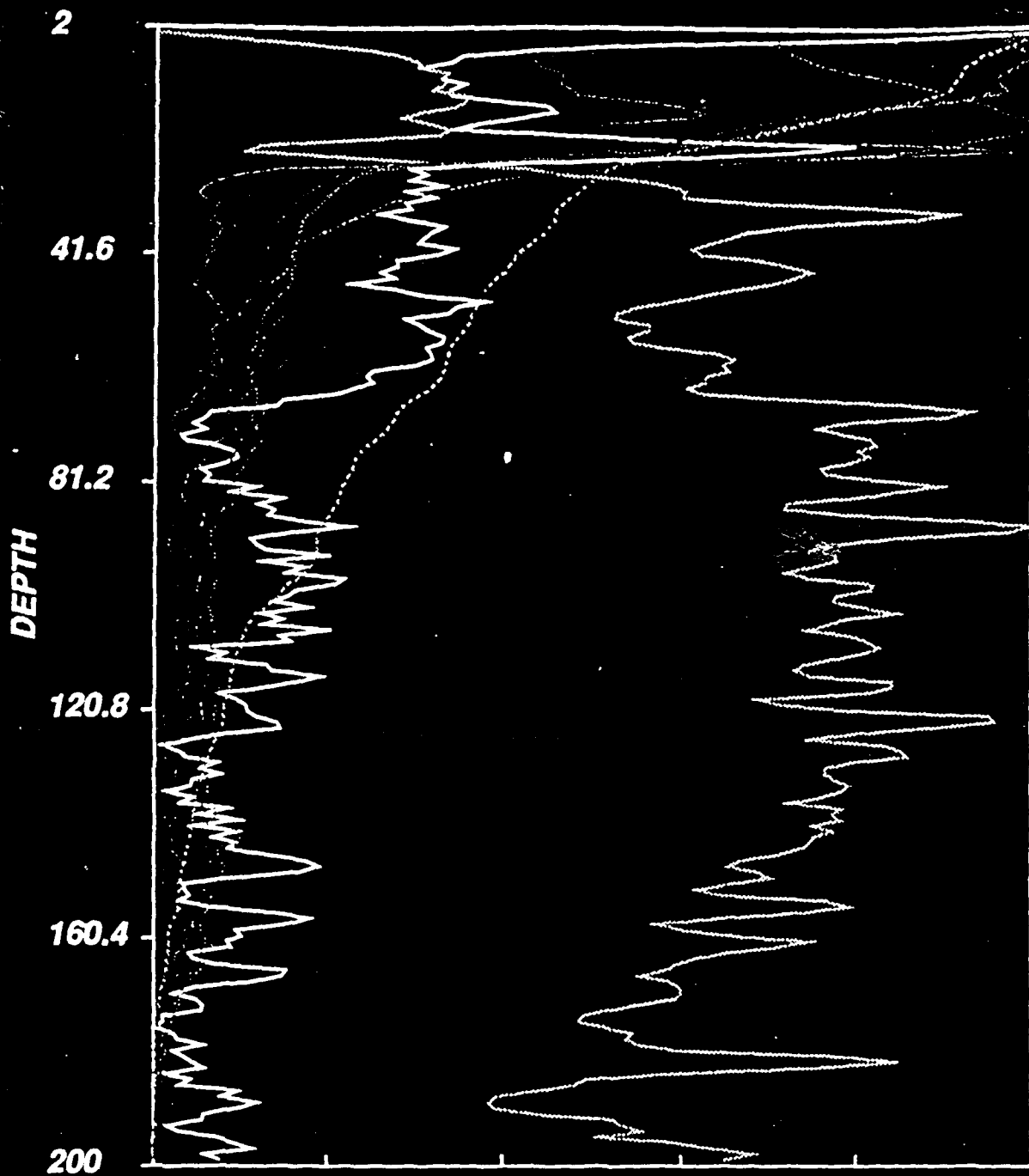
Event	3.27	4.73	6.19	7.65	9.11	10.6
Efold	0.309	0.372	0.435	0.498	0.562	0.625
Temp	13.3	13.8	14.3	14.9	15.4	15.9
Sal	35.8	36	36.2	36.4	36.6	36.8
Chlor	1.1	1.2	1.3	1.4	1.5	1.6
Fluor	0.272	0.342	0.411	0.481	0.551	0.621

Time : 23:35.18
 Date : 04/15/1991
 Cruise: MEP

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

prof st 12
 0062.pro



Event	2.58	3.93	5.27	6.62	7.96	9.3
Efold	0.321	0.384	0.448	0.512	0.575	0.639
Temp	13.4	13.9	14.5	15	15.6	16.1

T 0.245 0.333 0.419 0.504 0.589

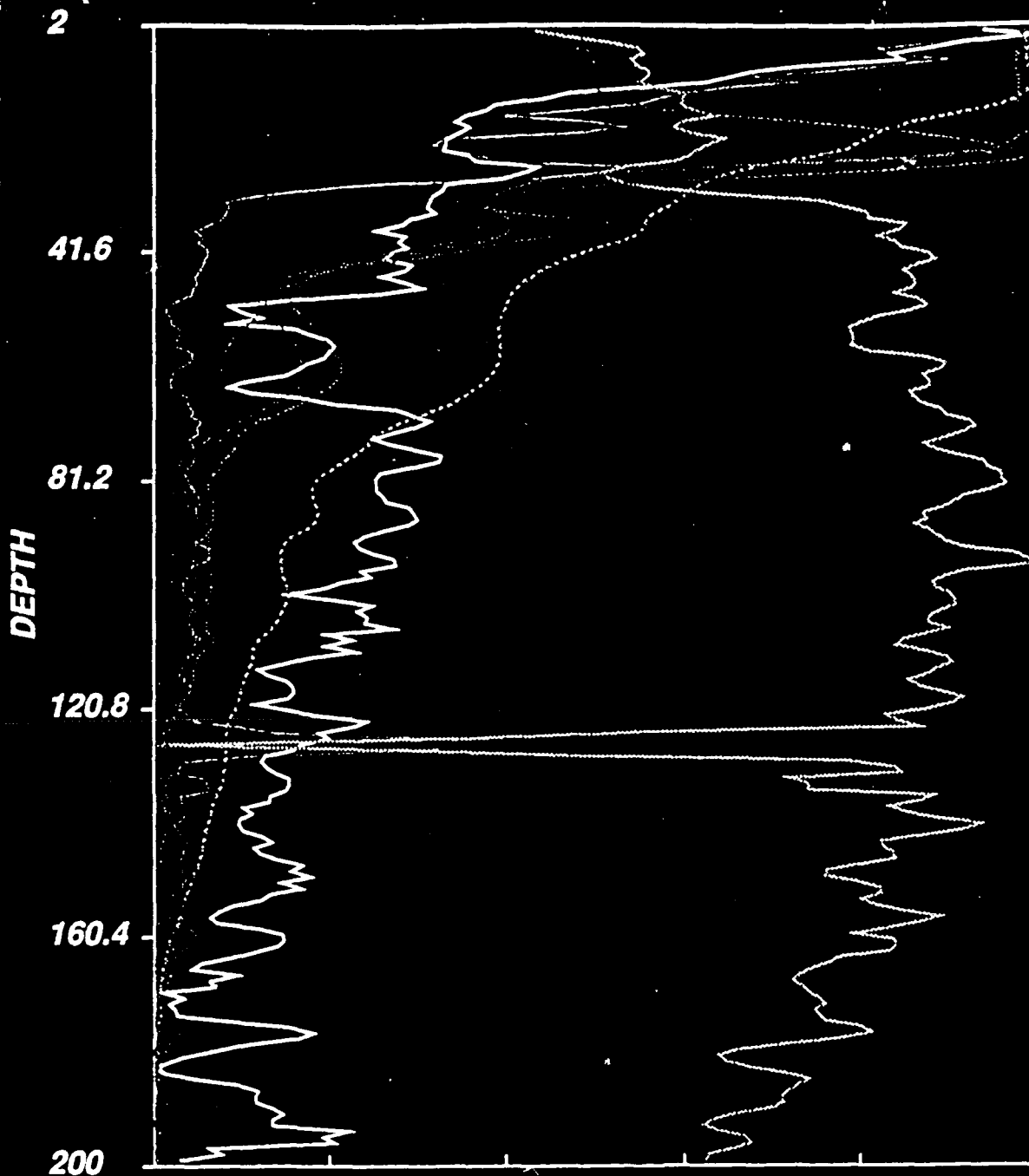
MEEX Software Version 2.0
 © 1990 by the MEEX Group, Inc.

Time : 02:03.28
 Date : 04/17/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

PROFILE 0068.pro



Event	2.57	3.94	5.32	6.69	8.07	9.44
Efold	0.0946	0.195	0.296	0.397	0.498	0.599
Temp	13.4	14	14.5	15.1	15.6	16.2

Blue	Green	Red	IR	IR2	IR3
0.258	0.342	0.426	0.51	0.599	

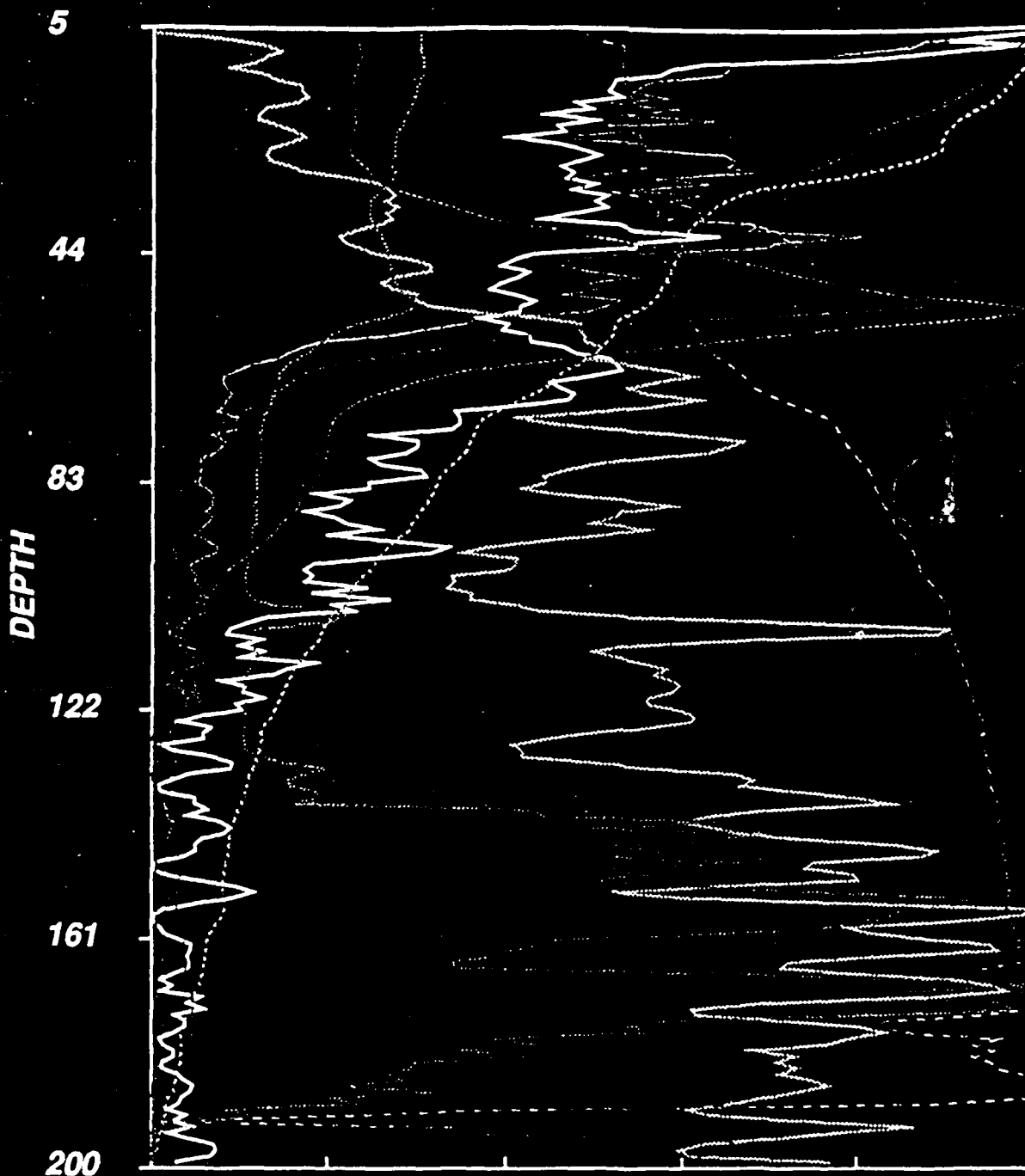
INDEX Software Version 3.0
 © Martin Marietta Group, 1991

Time : 00:49.47
 Date : 04/18/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type:
 Data File:

prof St 10
 0072.pro



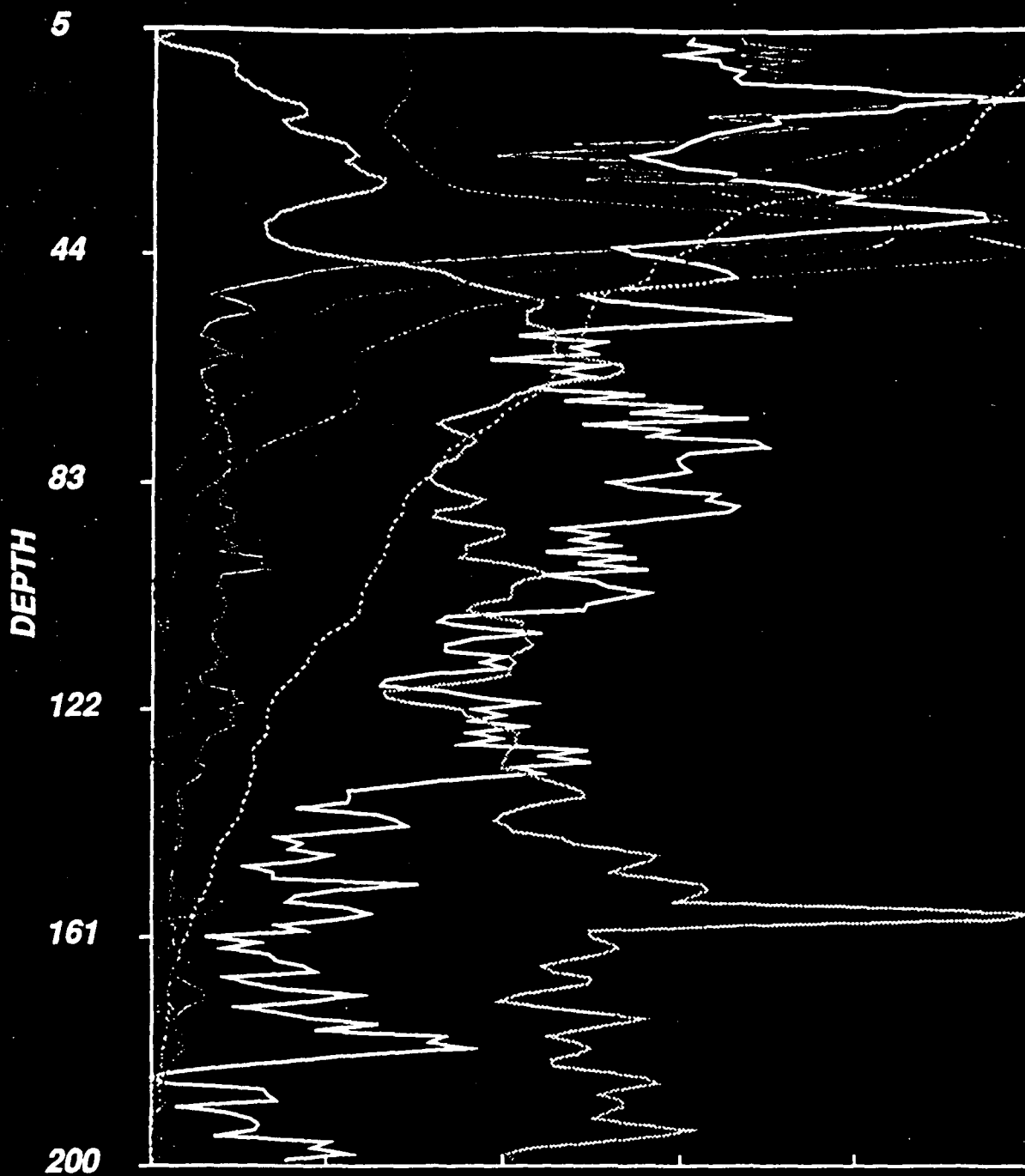
Event	2.47	3.67	4.87	6.07	7.27	8.47
Efold	0.391	0.436	0.48	0.525	0.569	0.614
Temp	13.5	14	14.5	15	15.5	16
T Diff	0.0024	0.403	0.71	1.02	1.32	

Time: 19:27.17
 Date: 04/19/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude: 000 000 00

Type:
 Data File:

PROF ST 14
 0076.pro

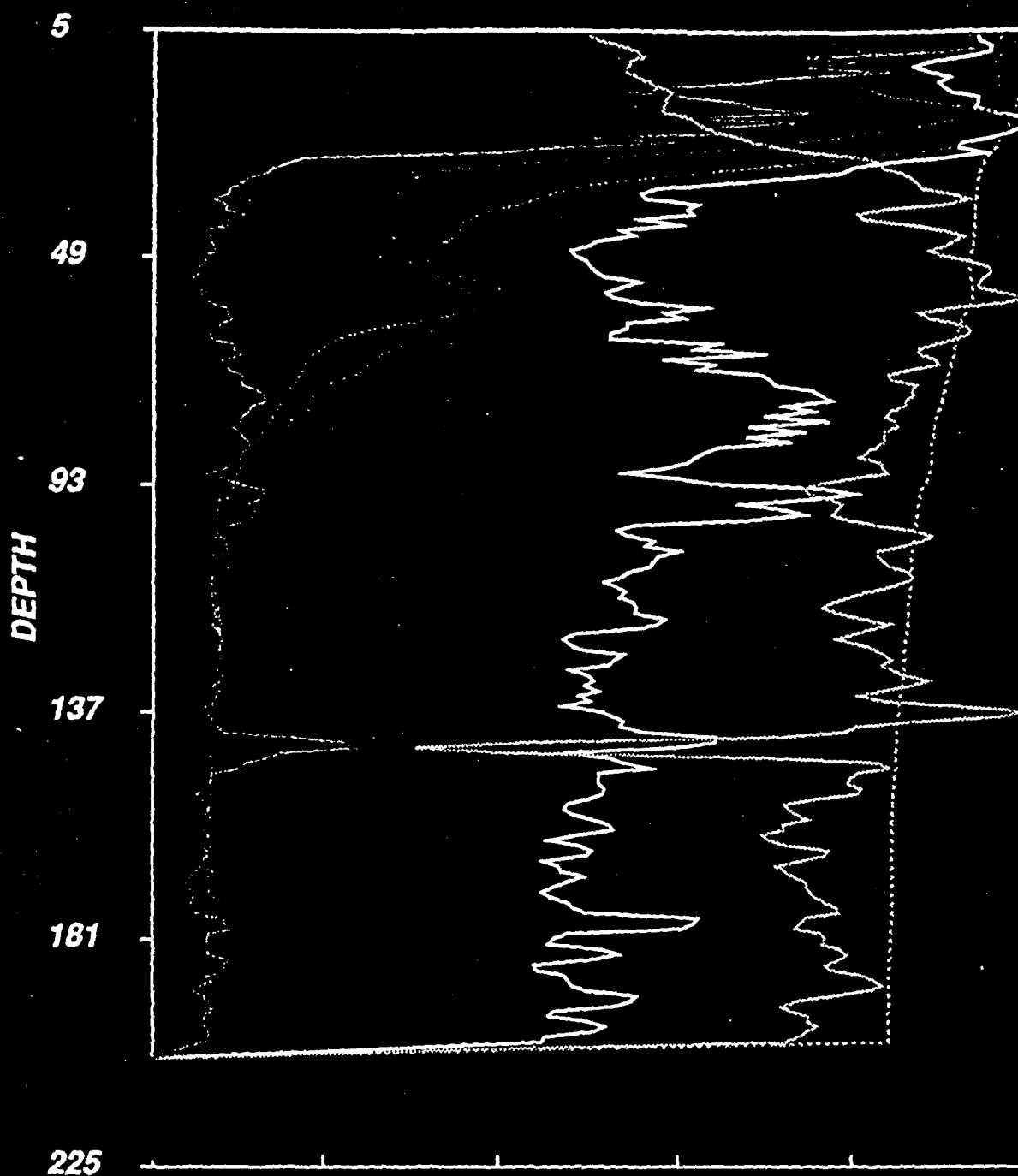


Event	2.55	3.31	4.08	4.84	5.6	6.37
Efold	0.342	0.426	0.511	0.596	0.681	0.765
Temp	13.5	14	14.5	15	15.5	16

Time : 23:04.59
 Date : 04/20/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00
 Type: Data File:

PROF ST 15
 0078.pro



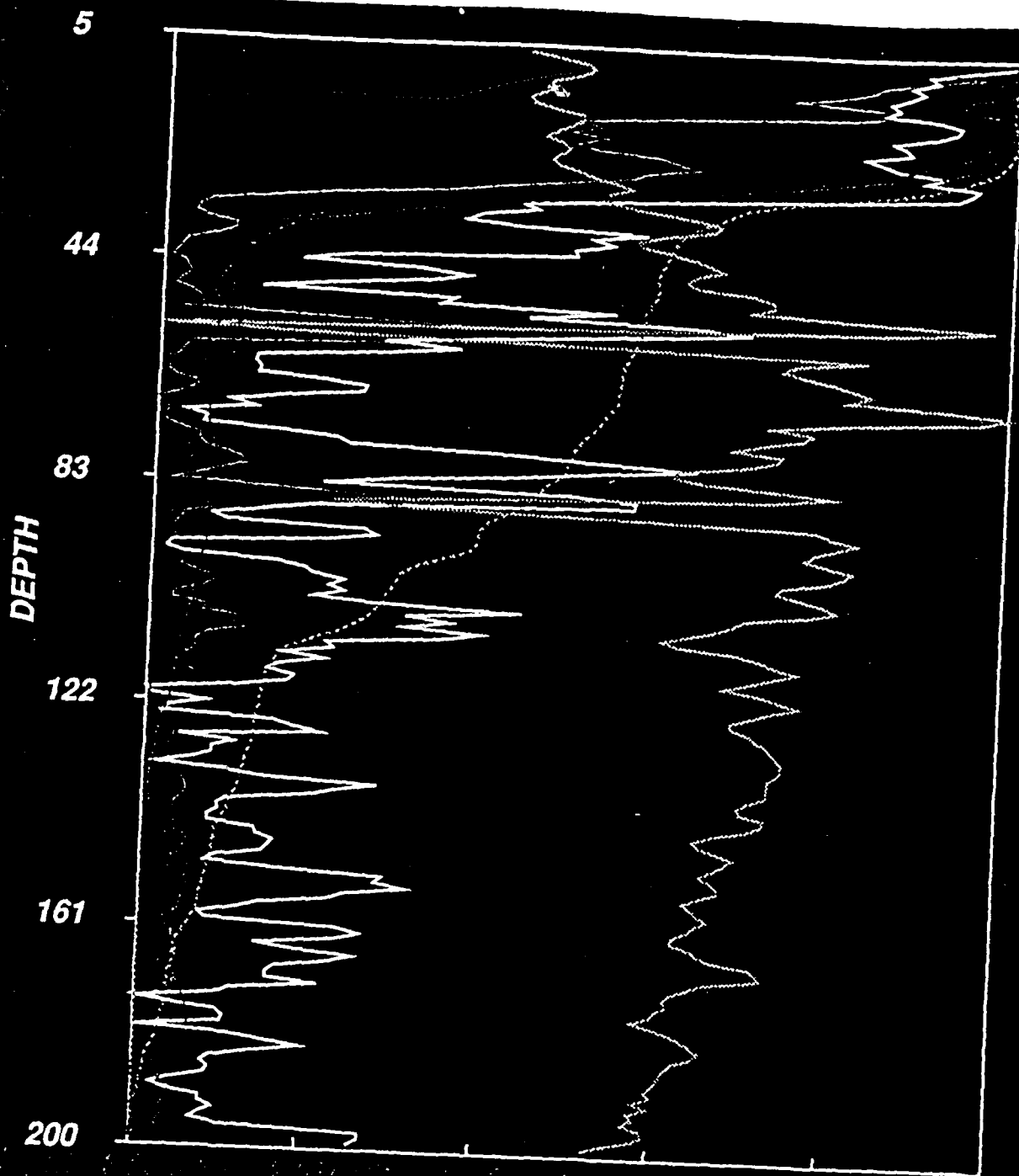
Event 0	1.06	2.11	3.17	4.22	5.28
Efold 0	0.137	0.273	0.41	0.547	0.684
Temp 0	3.2	6.4	9.59	12.8	16

Time : 22:22.55
 Date : 04/21/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

PROFILE ST16
 0088.pro

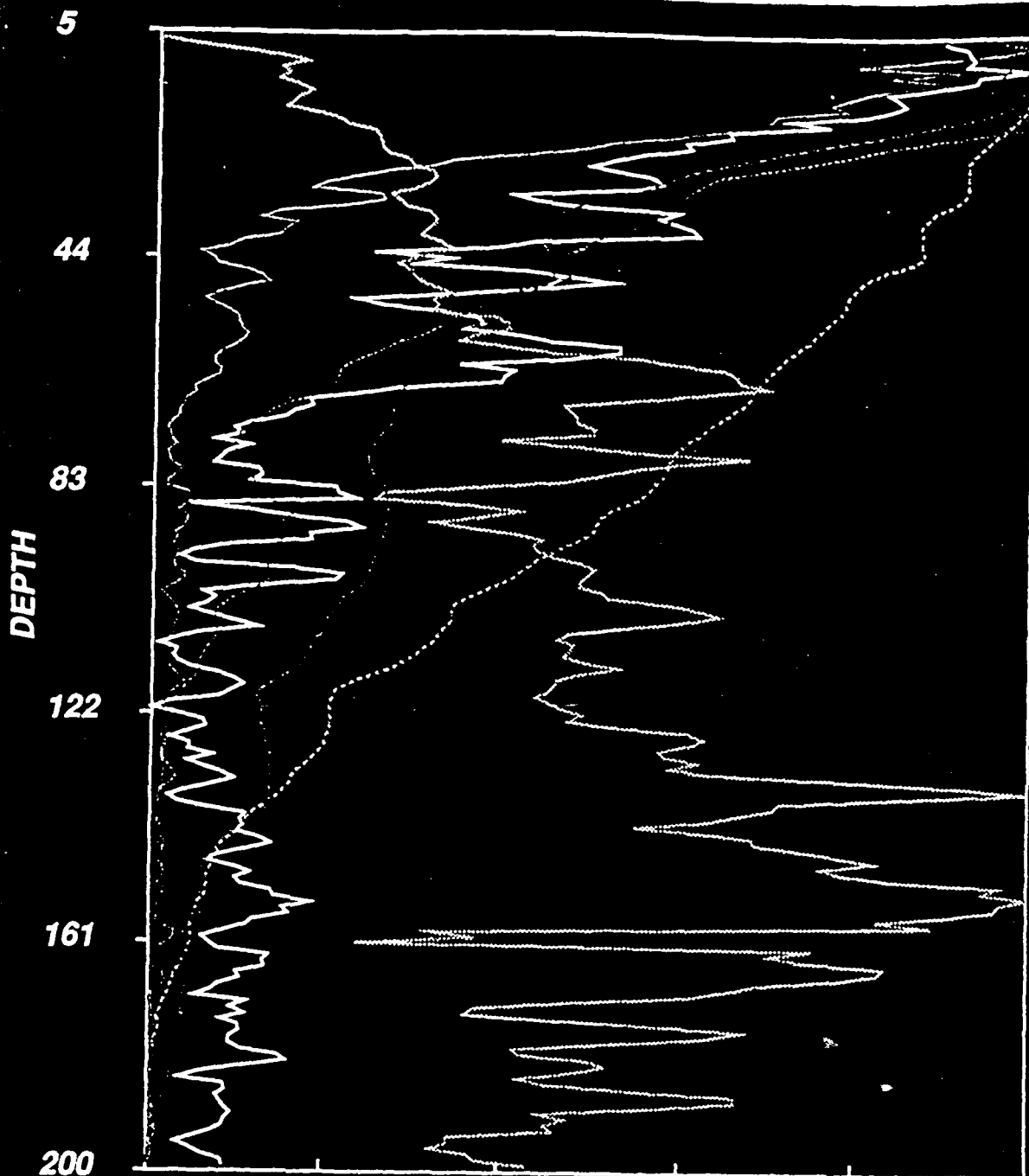


Time : 00:09.08
 Date : 04/23/1991
 Cruise: MED

Longitude: 000 000 00
 Latitude : 000 000 00

Type: Data File:

PROF ST 17
 0094.pro



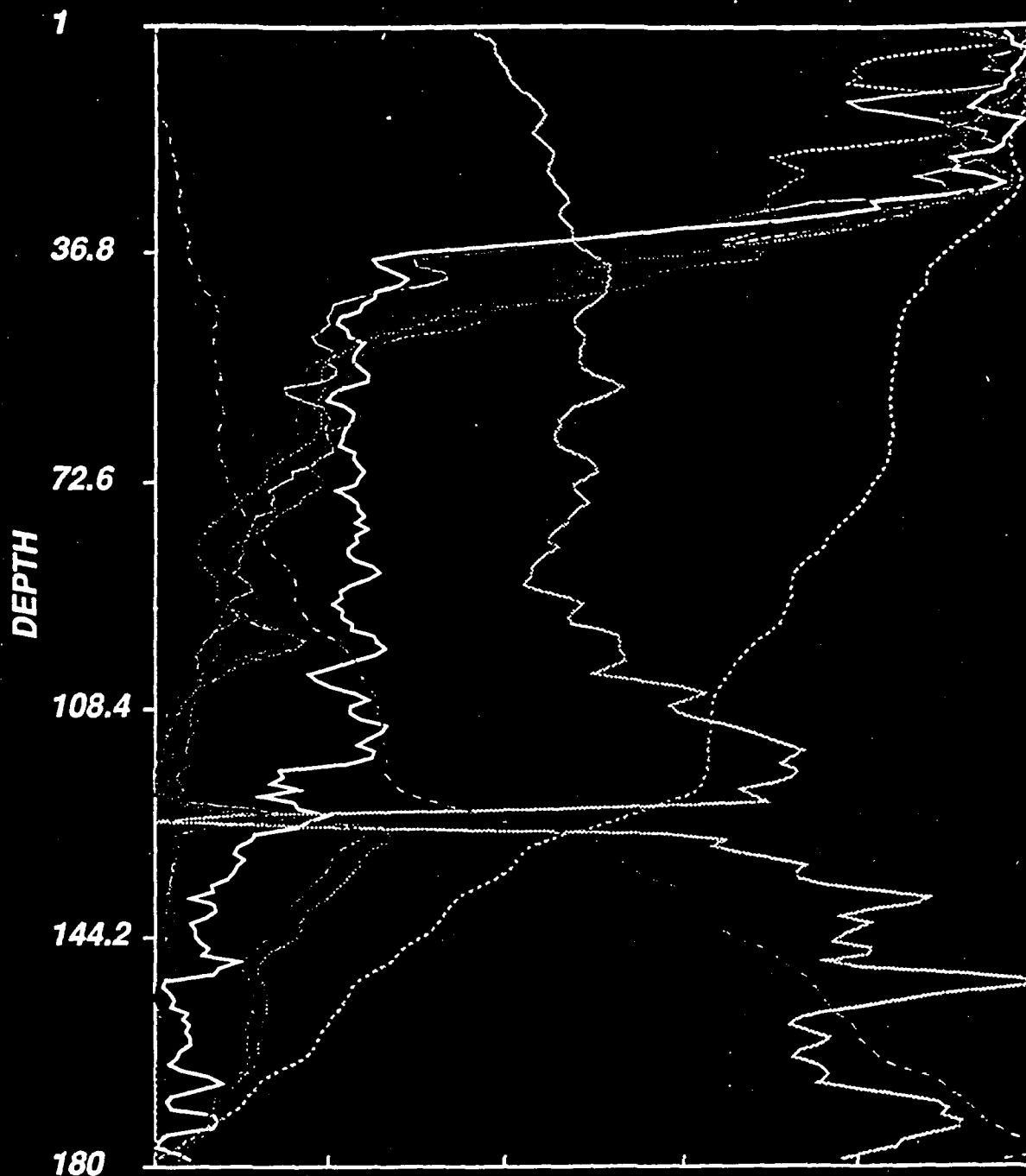
	2.33	3.2	4.07	4.94	5.81	6.67
Event	0.362	0.454	0.546	0.637	0.729	0.821
Efold	13.5	14	14.4	14.9	15.3	15.7
Temp						

Time : 01:04.10
Date : 04/24/1991
Cruise: MED

Longitude: 000 000 00
Latitude : 000 000 00

Type:
Data File:

PROF ST 2
0102.pro



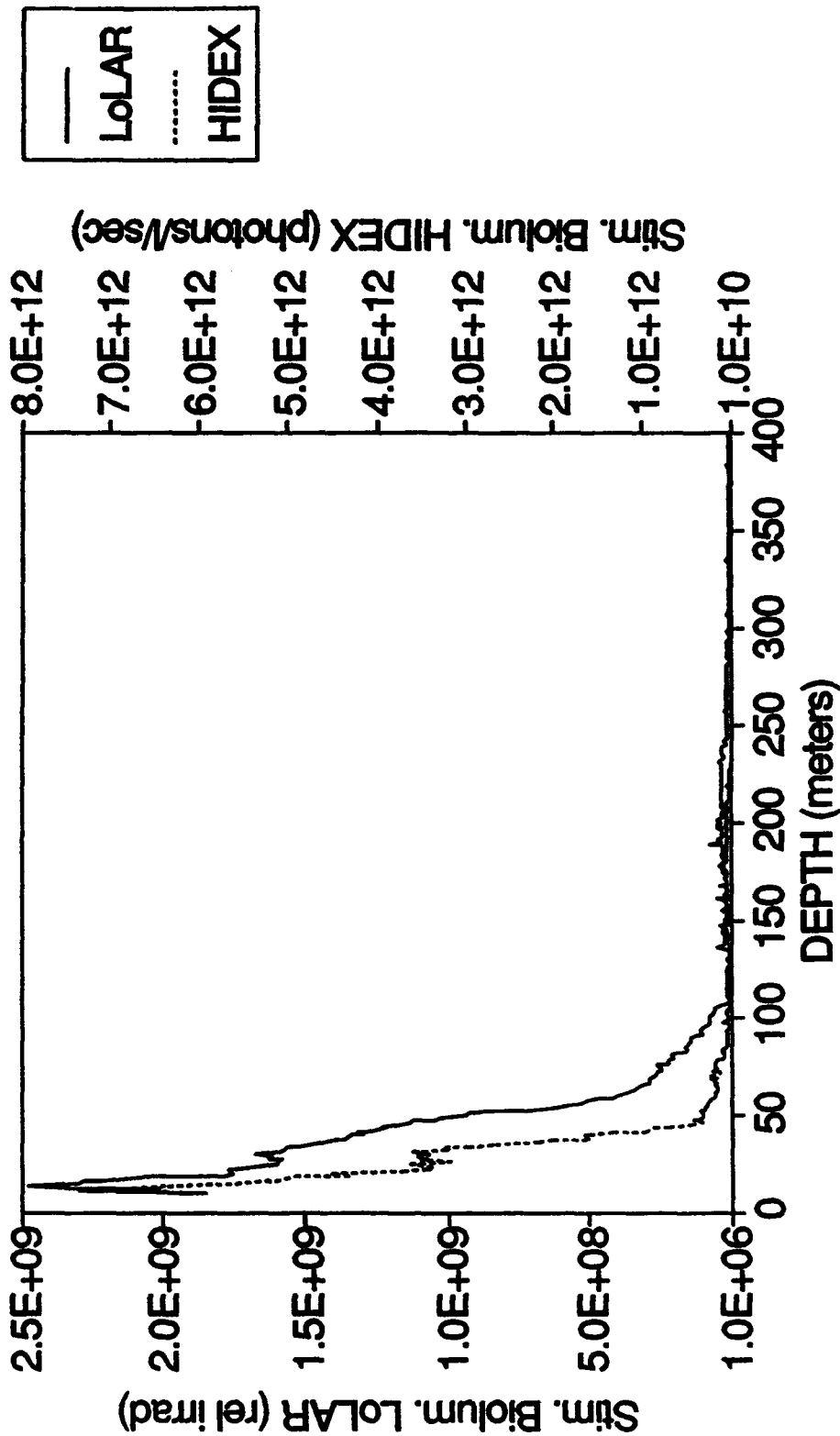
	1.00	1.25	1.50	1.75	2.00	2.25
Event	2.34	4.28	6.22	8.16	10.1	12
Efold	0.204	0.302	0.399	0.496	0.594	0.691
Temp	13.6	14.1	14.5	14.9	15.3	15.7
Salin	35.5	35.4	35.2	35	34.8	34.6
Fluor	161	443	712	983	1254	1525
T Red	0.0559	0.118	0.174	0.233	0.292	0.351
T Blue	0.305	0.373	0.442	0.511	0.579	0.648

INDEX Software Version 3.0
© 1999 International Business Machines Corporation, 2000

Appendix B - HIDEX vs. LoLAR Profiles

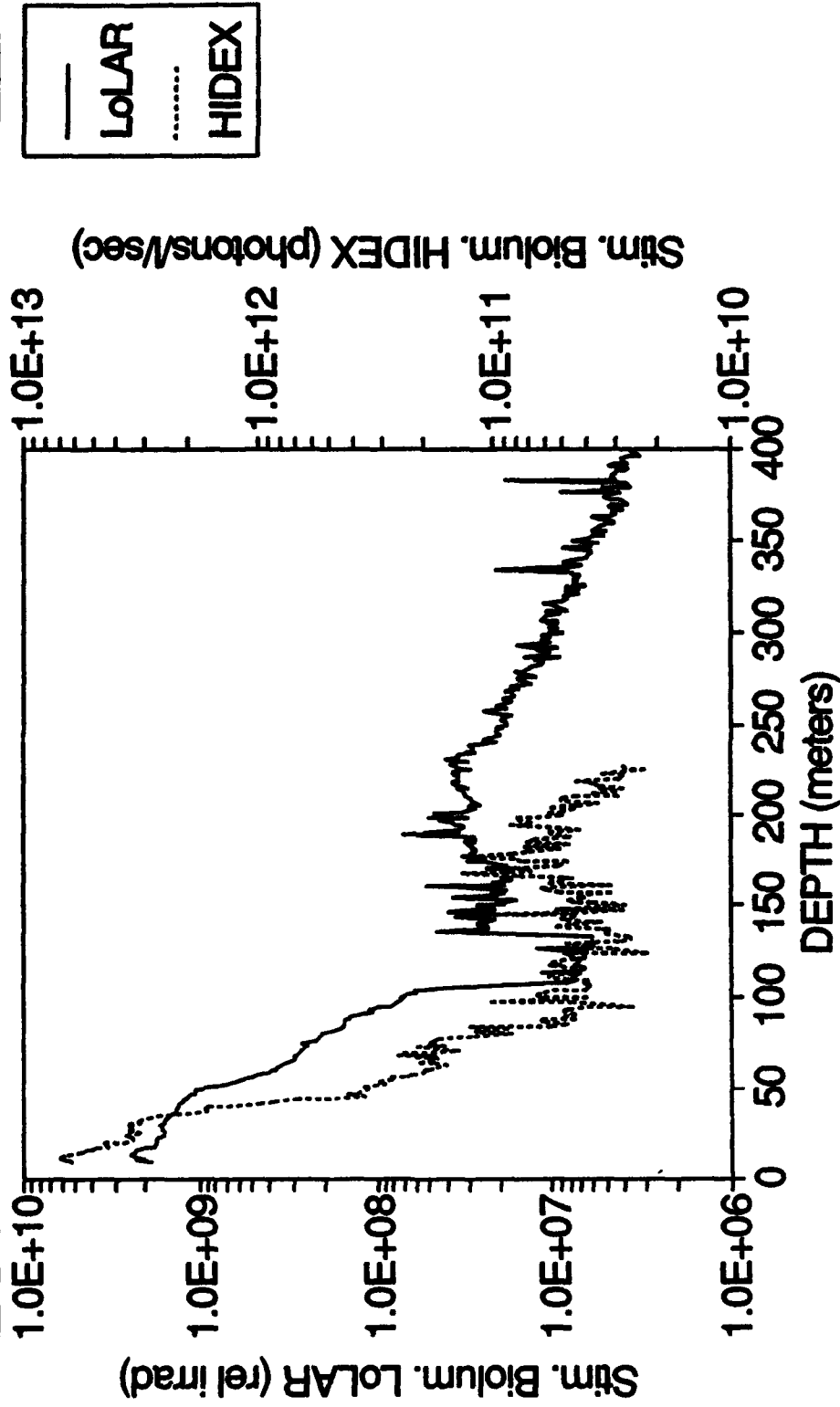
HIDEX and LoLAR Profiles

Station 3 6-APR-91

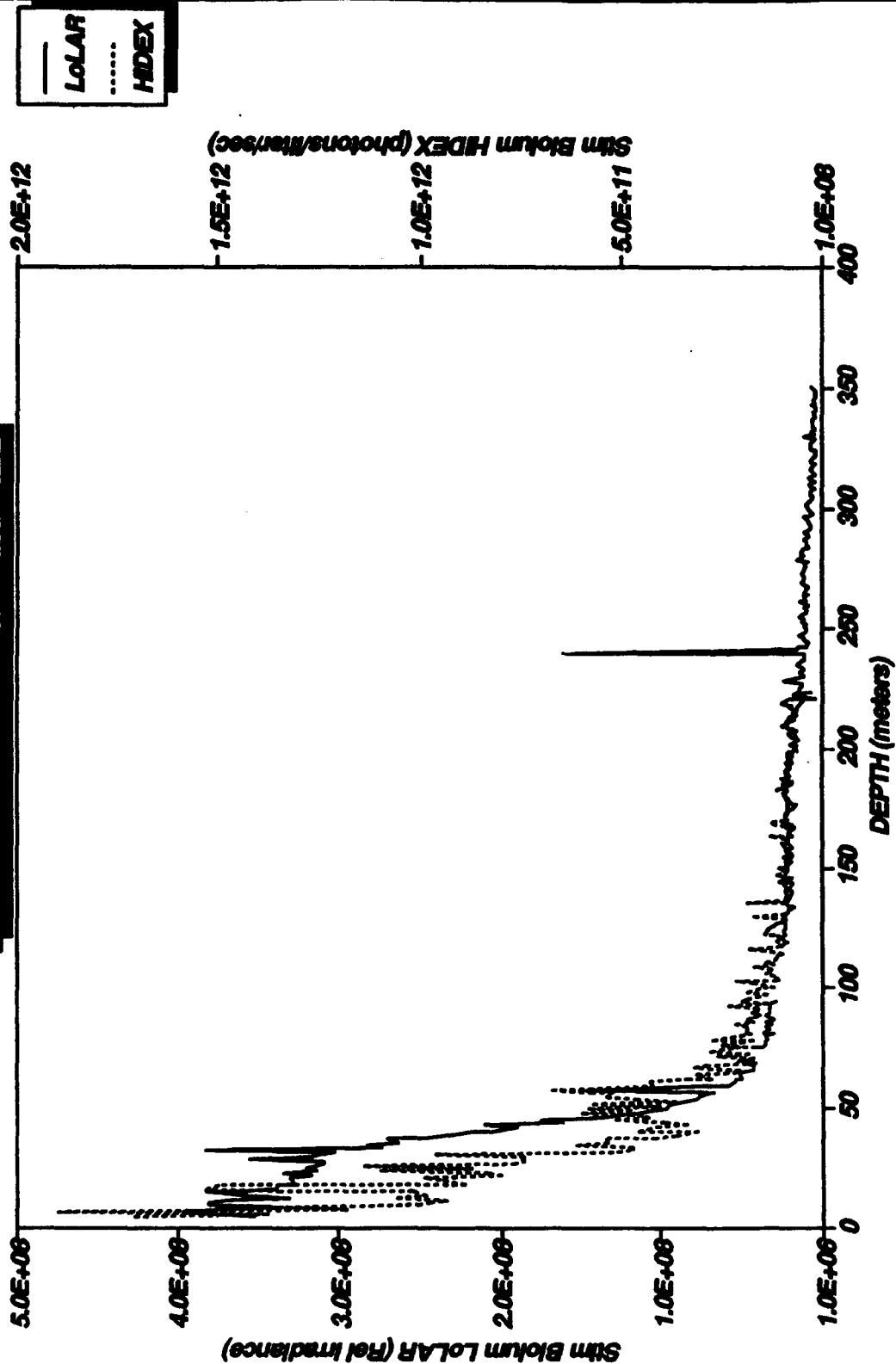


HIDEX and LoLAR Profiles (Log Scale)

Station 3 6-APR-91

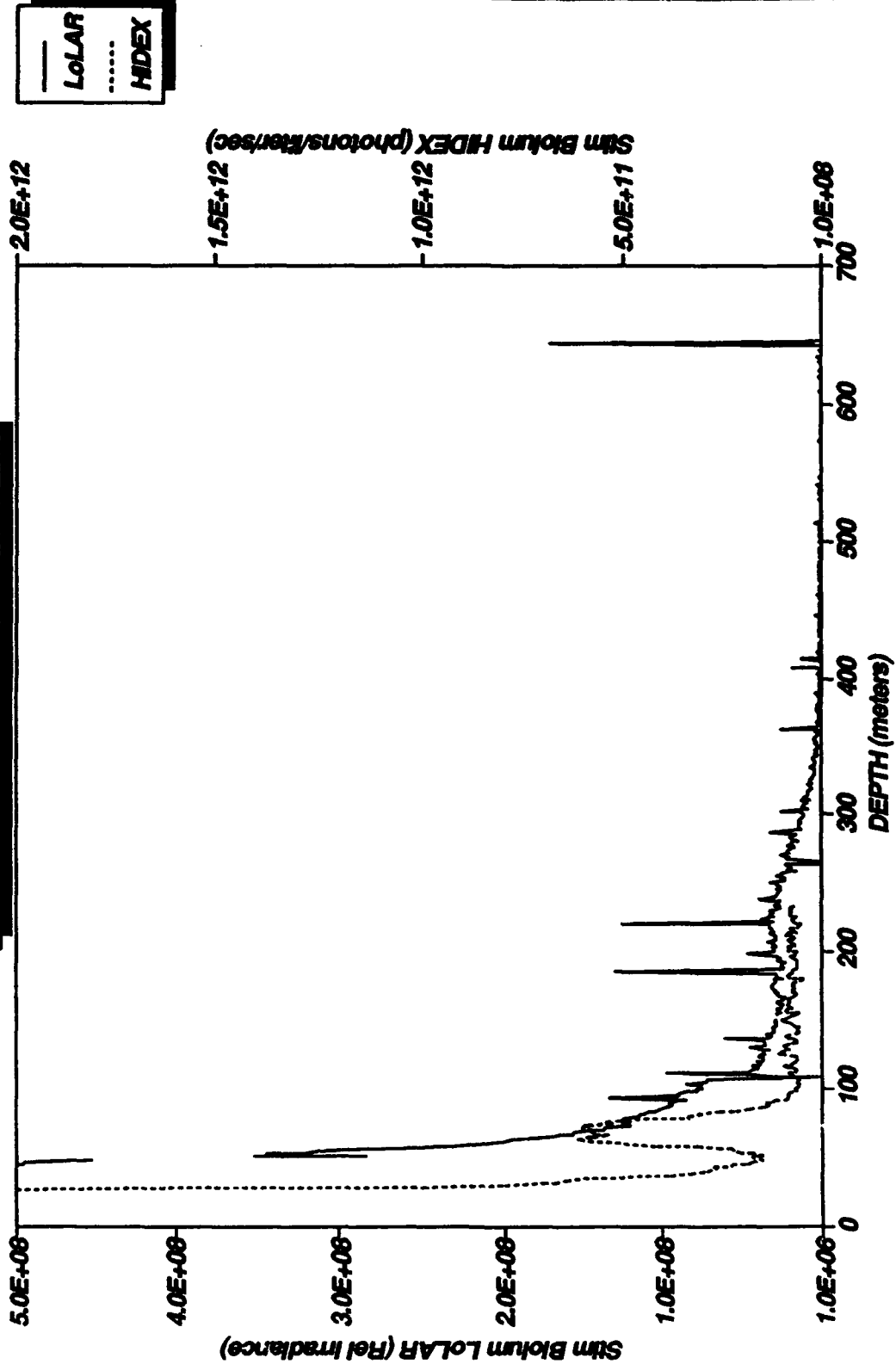


HIDEX and LOLAR PROFILES Station 4 7-APR-81

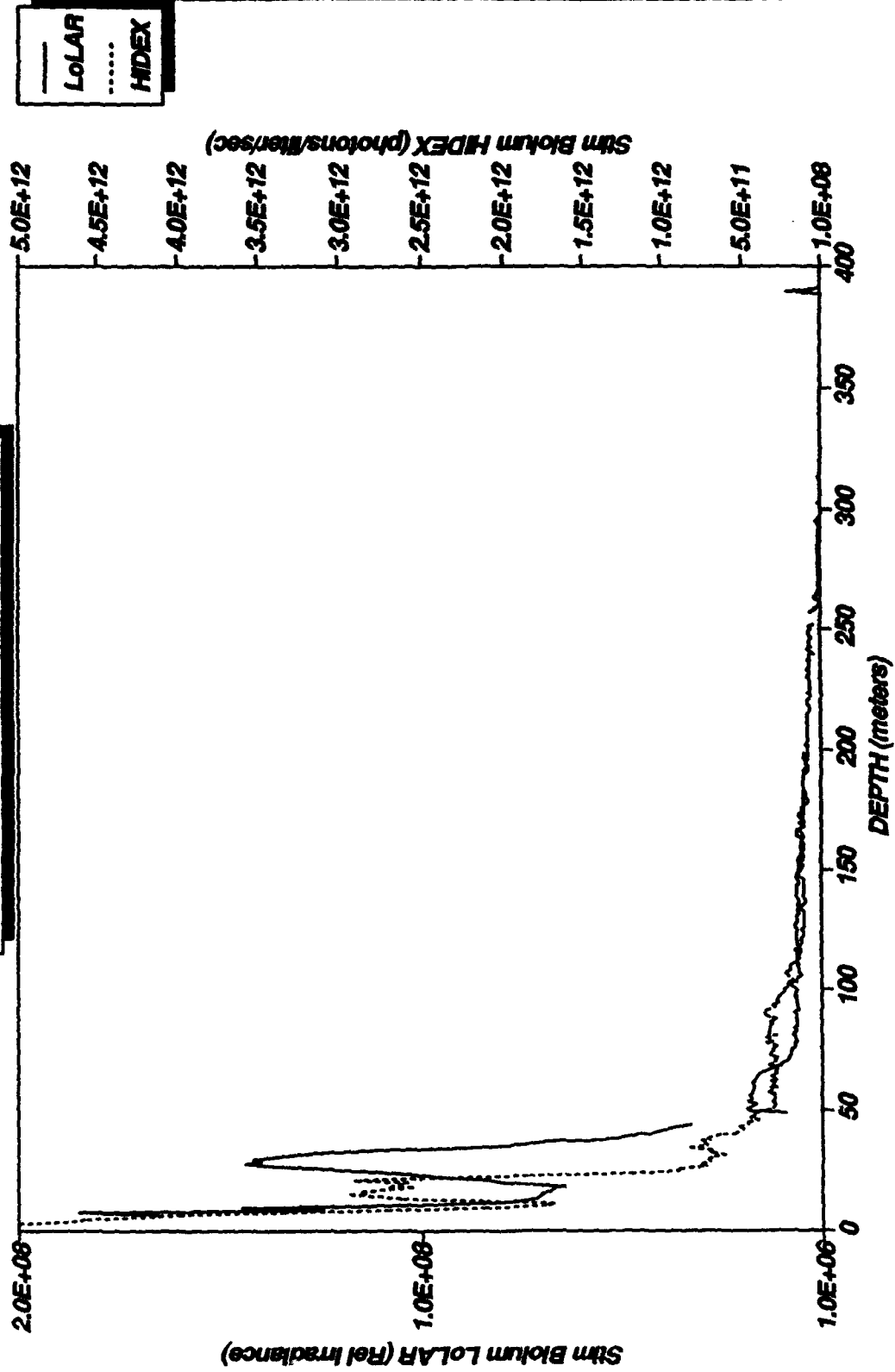


HIDEX and LoLAR PROFILES

Station 6 9-APR-01

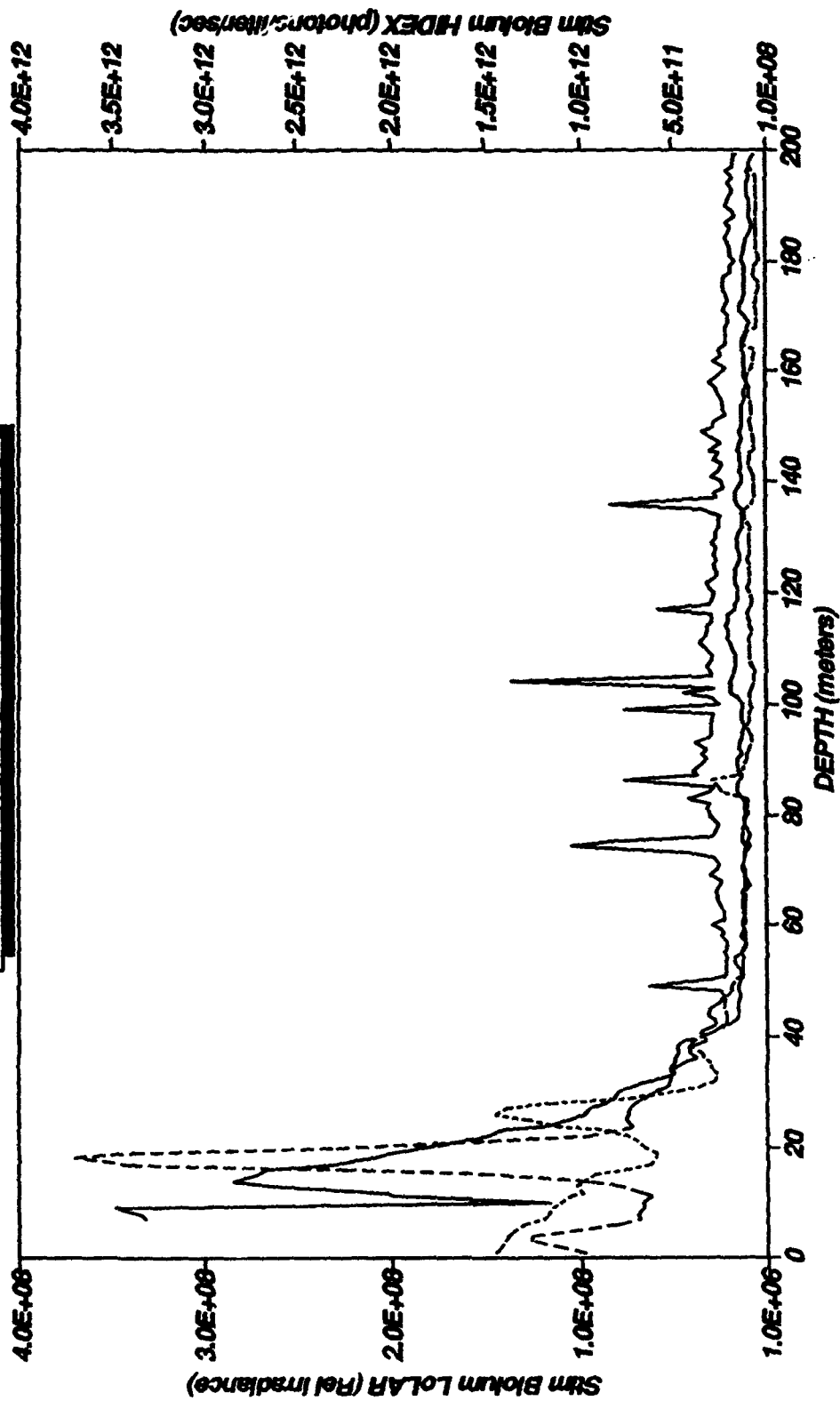


HIDEX and LoLAR PROFILES Station 9 11-APR-81



HIDEX and LoLAR PROFILES

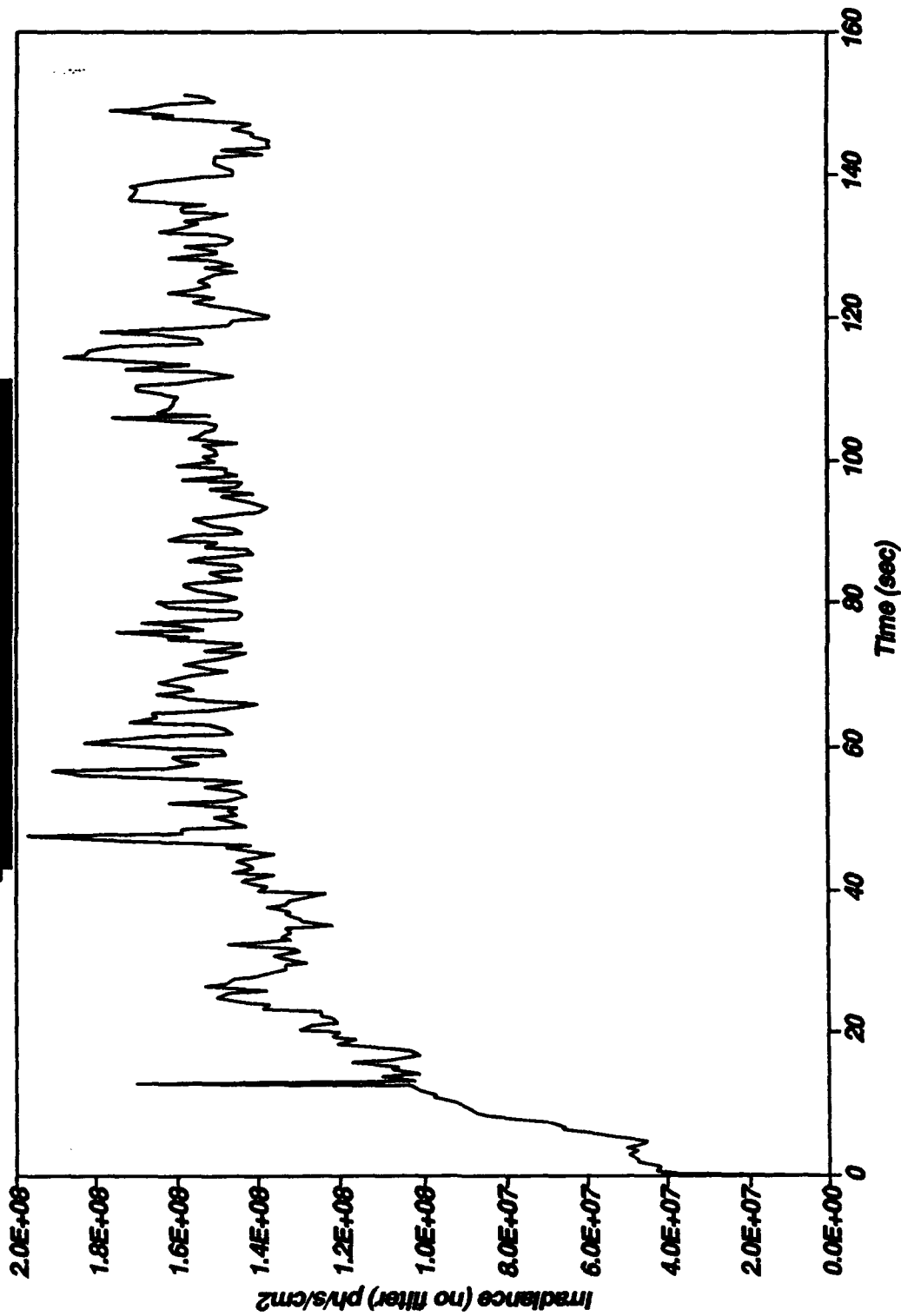
Station 12 16-APR-01



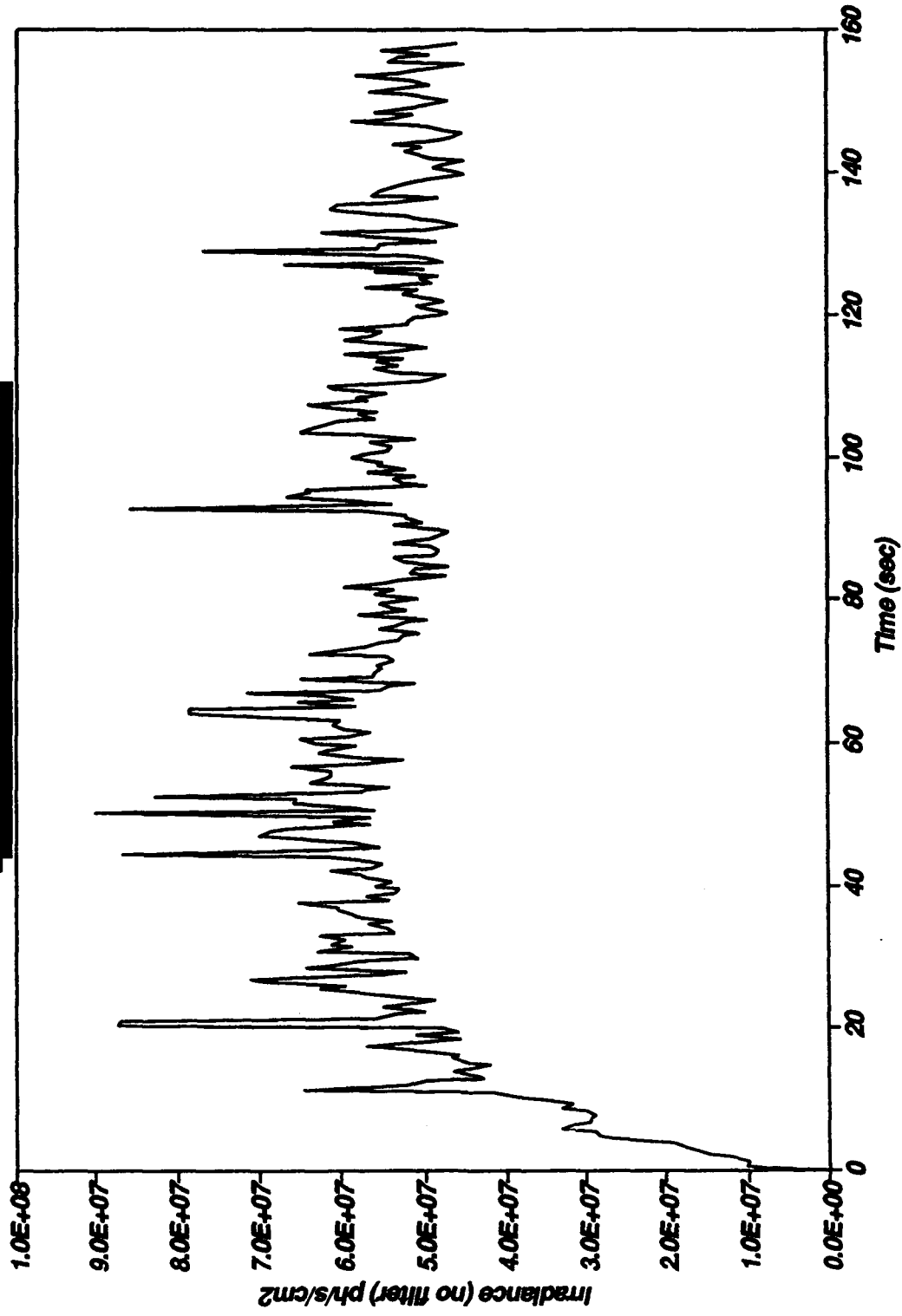
Appendix C - Transects

Station 4 Transect Data

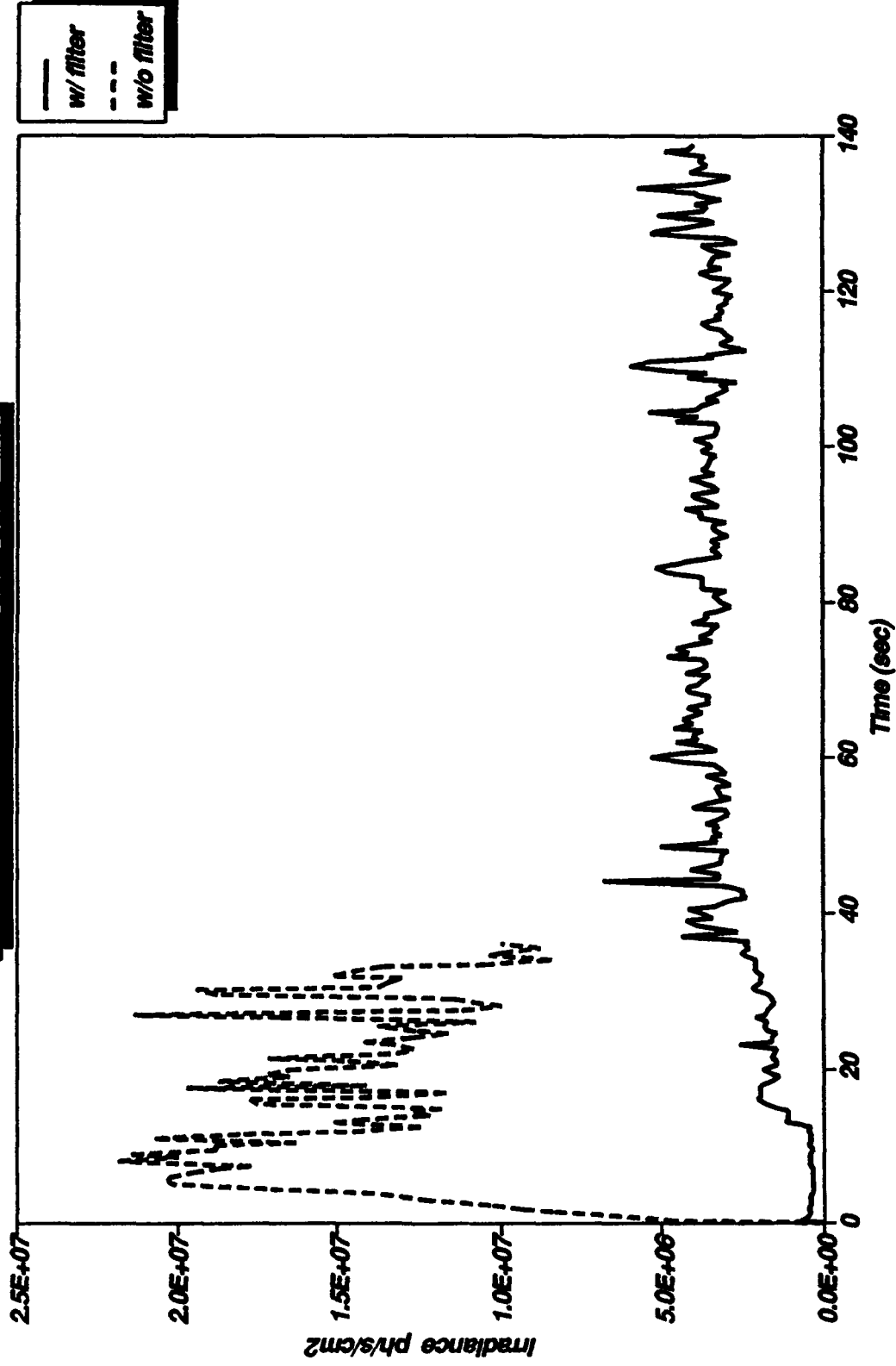
LoLAR Transect 2932J.TRA
Station 4 7-APR-91 28 m



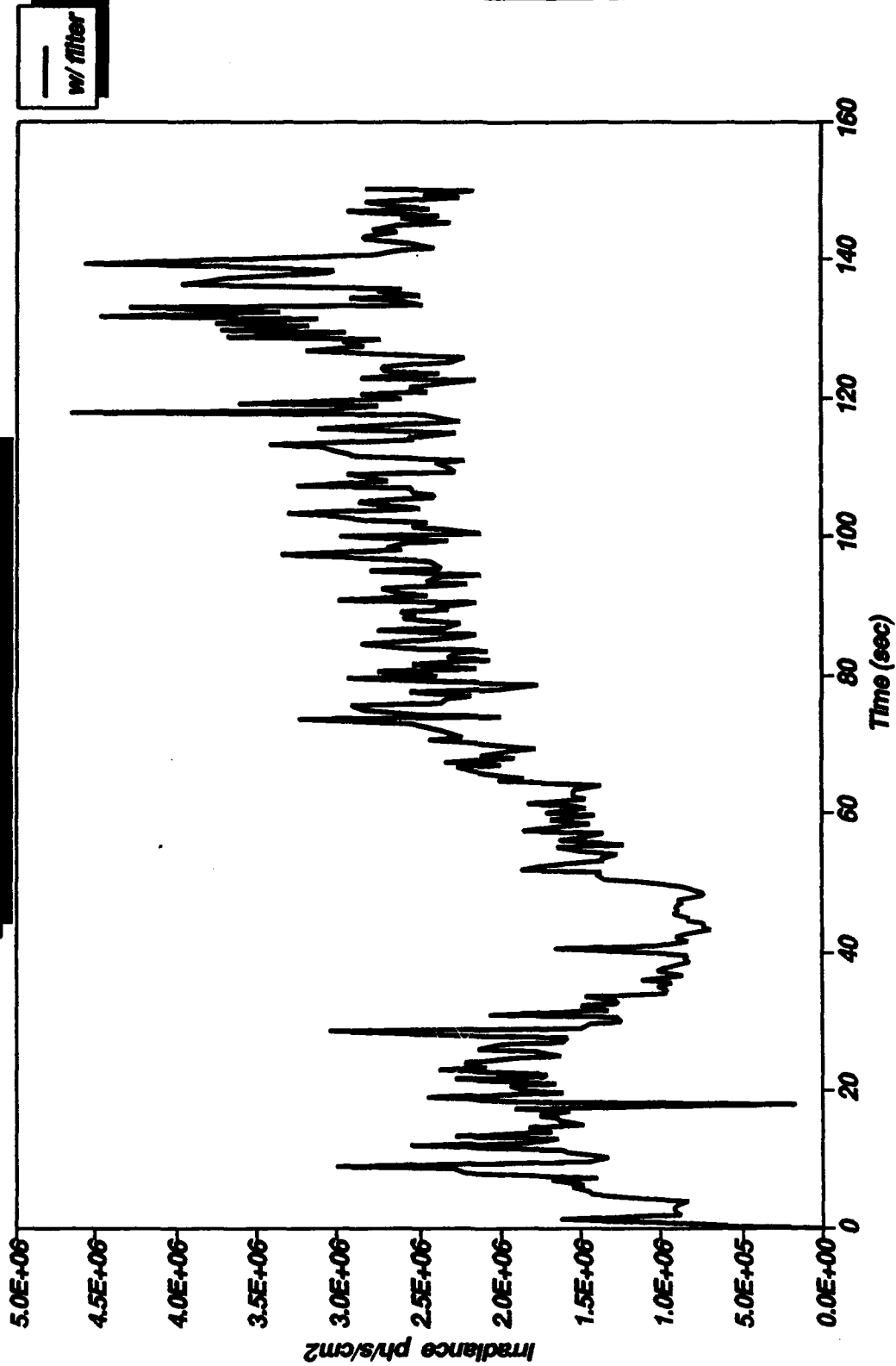
LoLAR Transect 29321.TRA
Station 4 7-APR-01 68 m



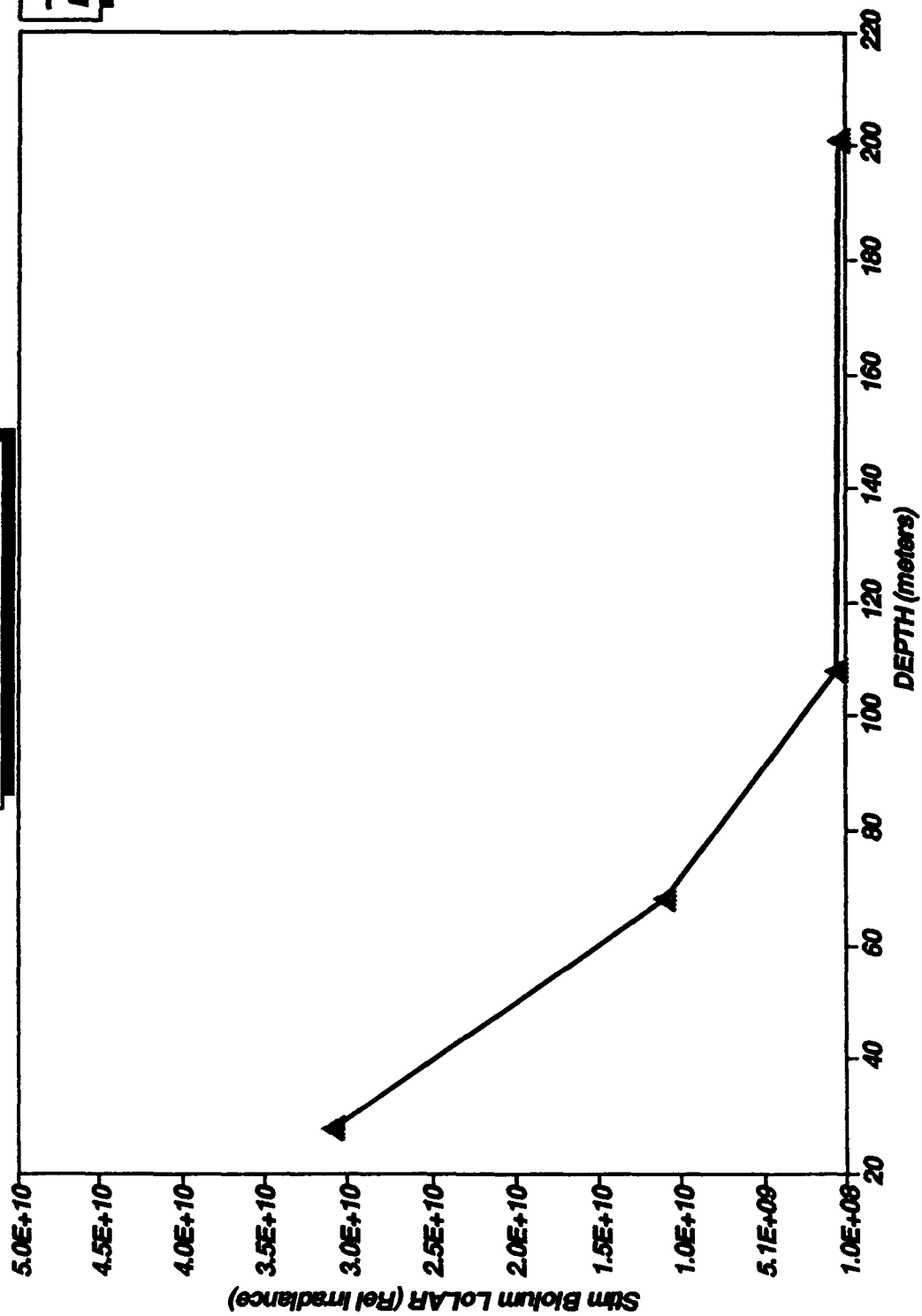
LoLAR Transect 2932G&H.TRA
Station 4 7-APR-91 107 m



LOLAR Transect 2932F.TRA
Station 4 7-APR-91 202 m

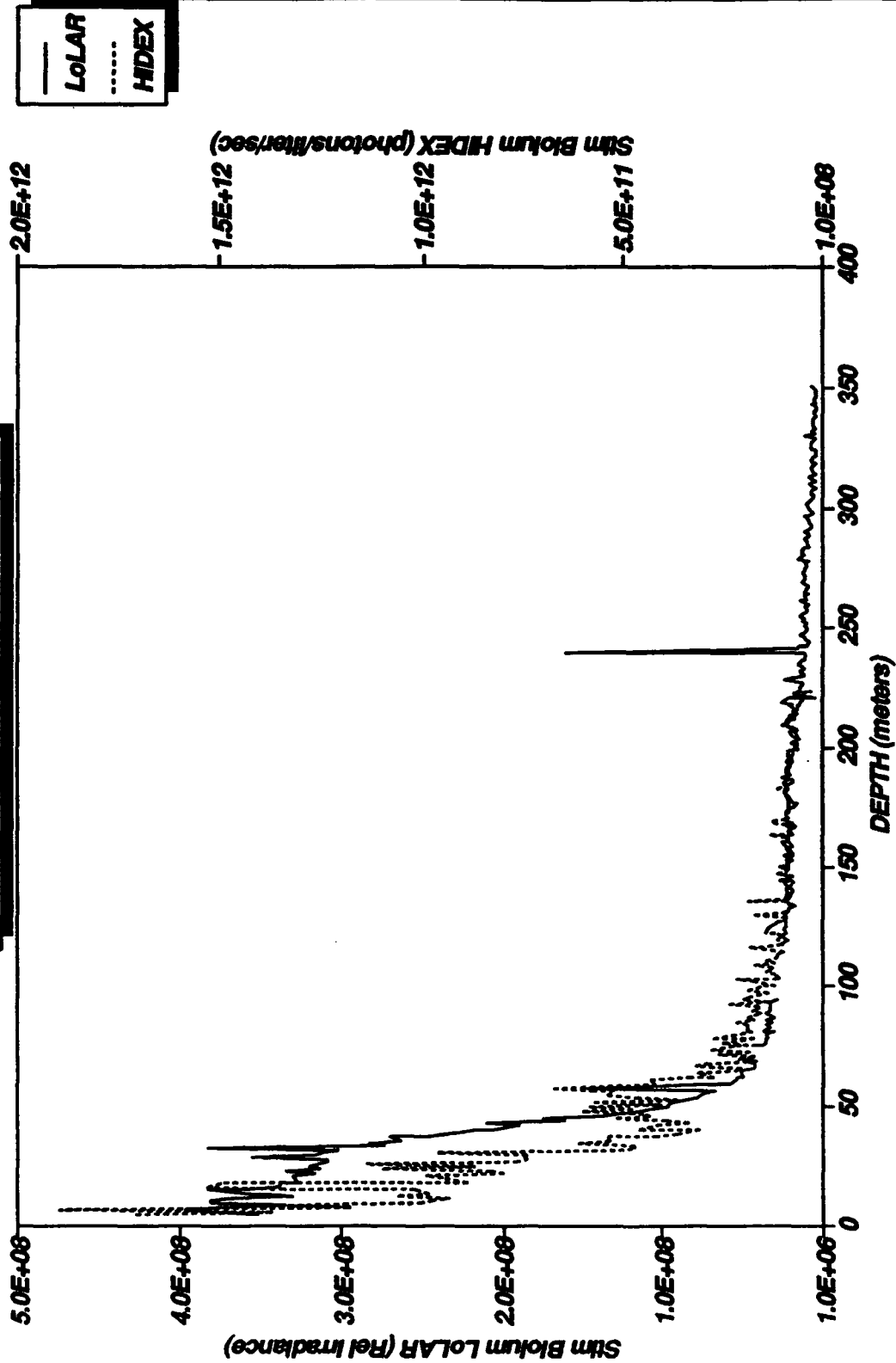


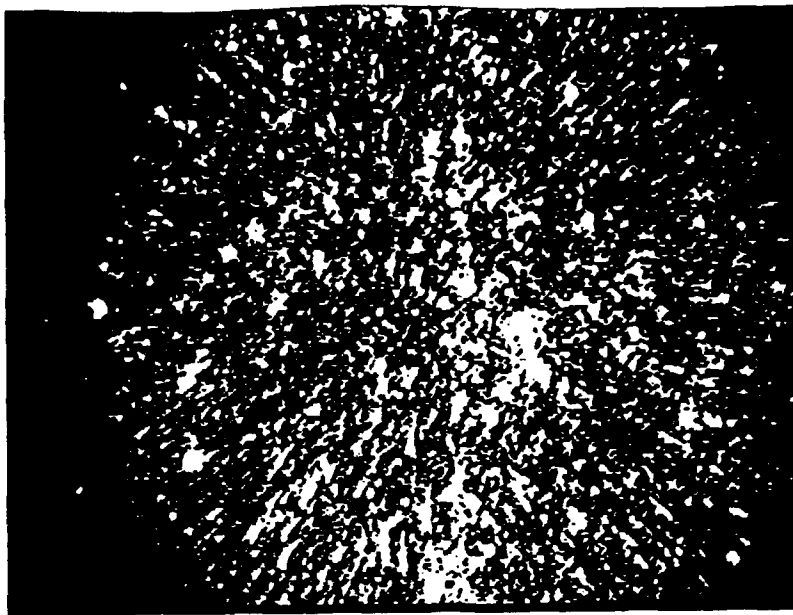
LOLAR TRANSECTS
Station 4 7-APR-91



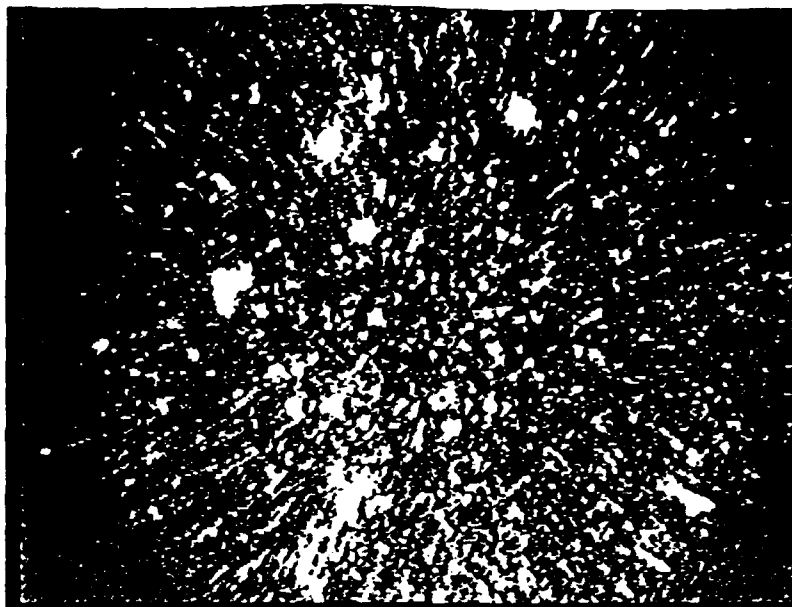
HIDEX and LoLAR PROFILES

Station 4 7-APR-91

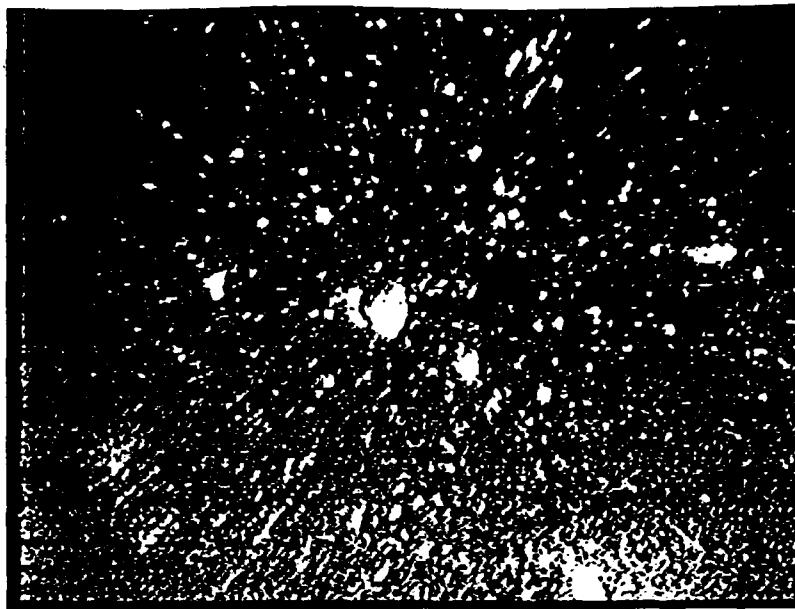




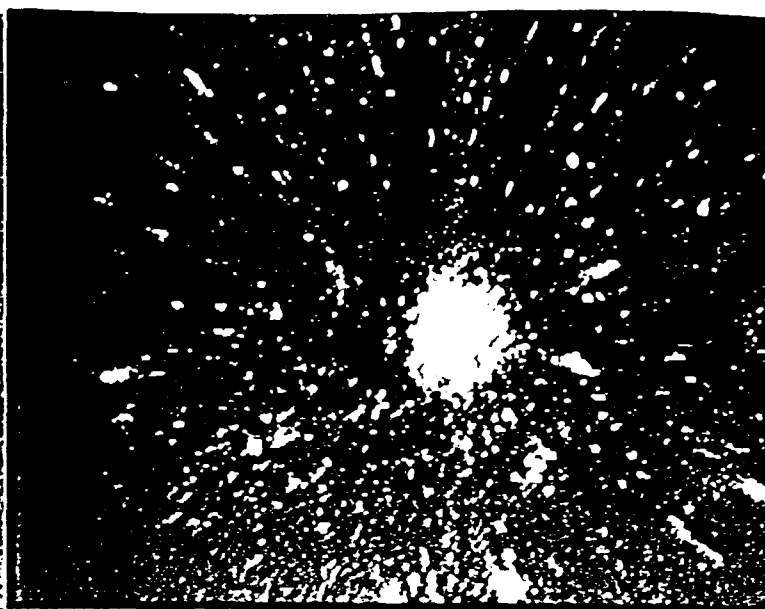
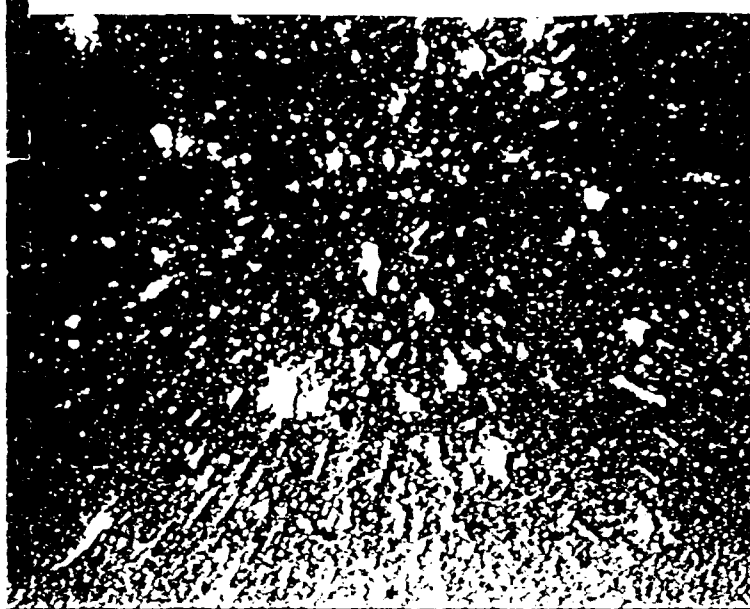
Video still-frame of transect at 25 m, Station 4



64 m Station 4



95 m Station 4

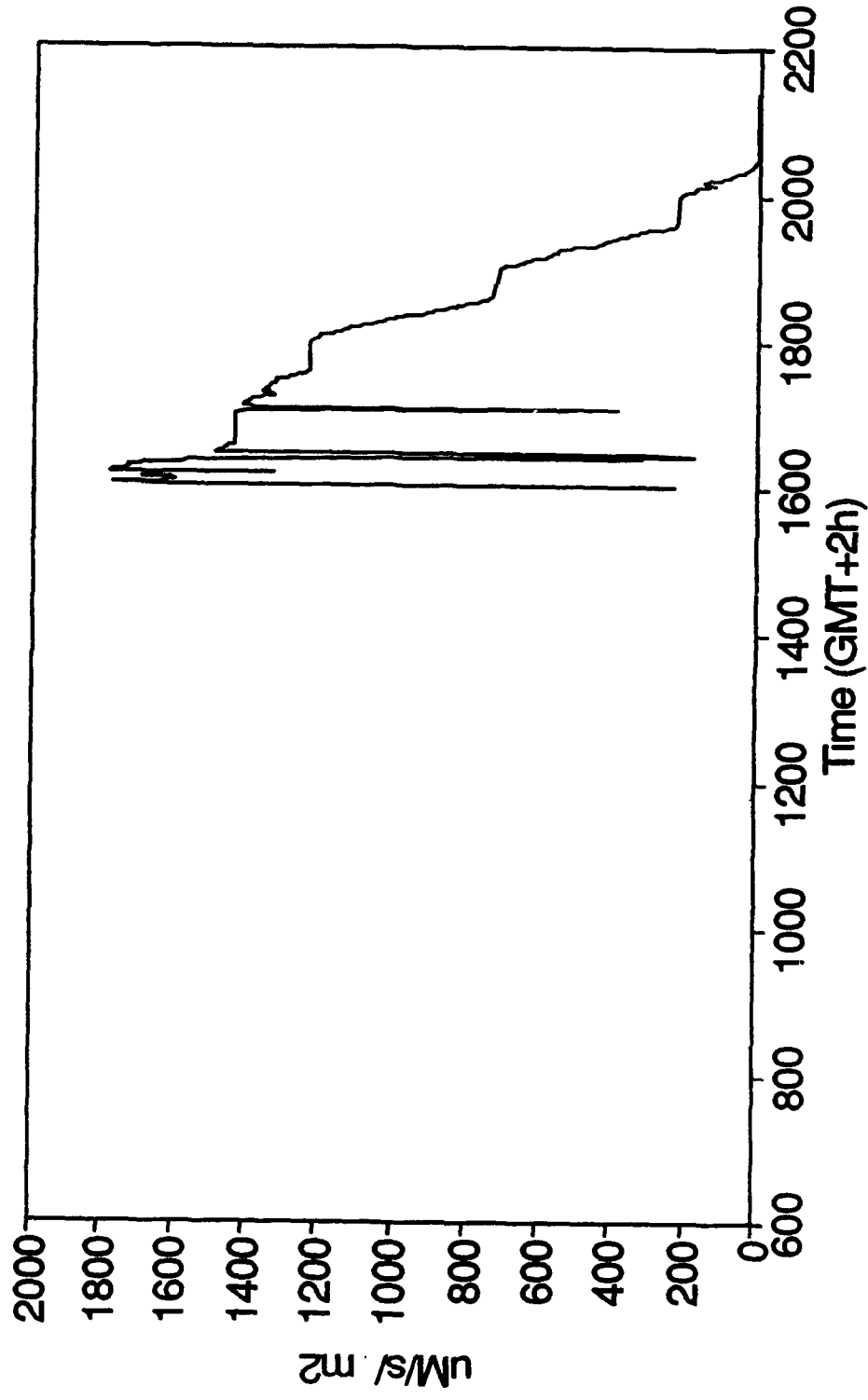


183 m Station 4

Appendix D - Solar Irradiance

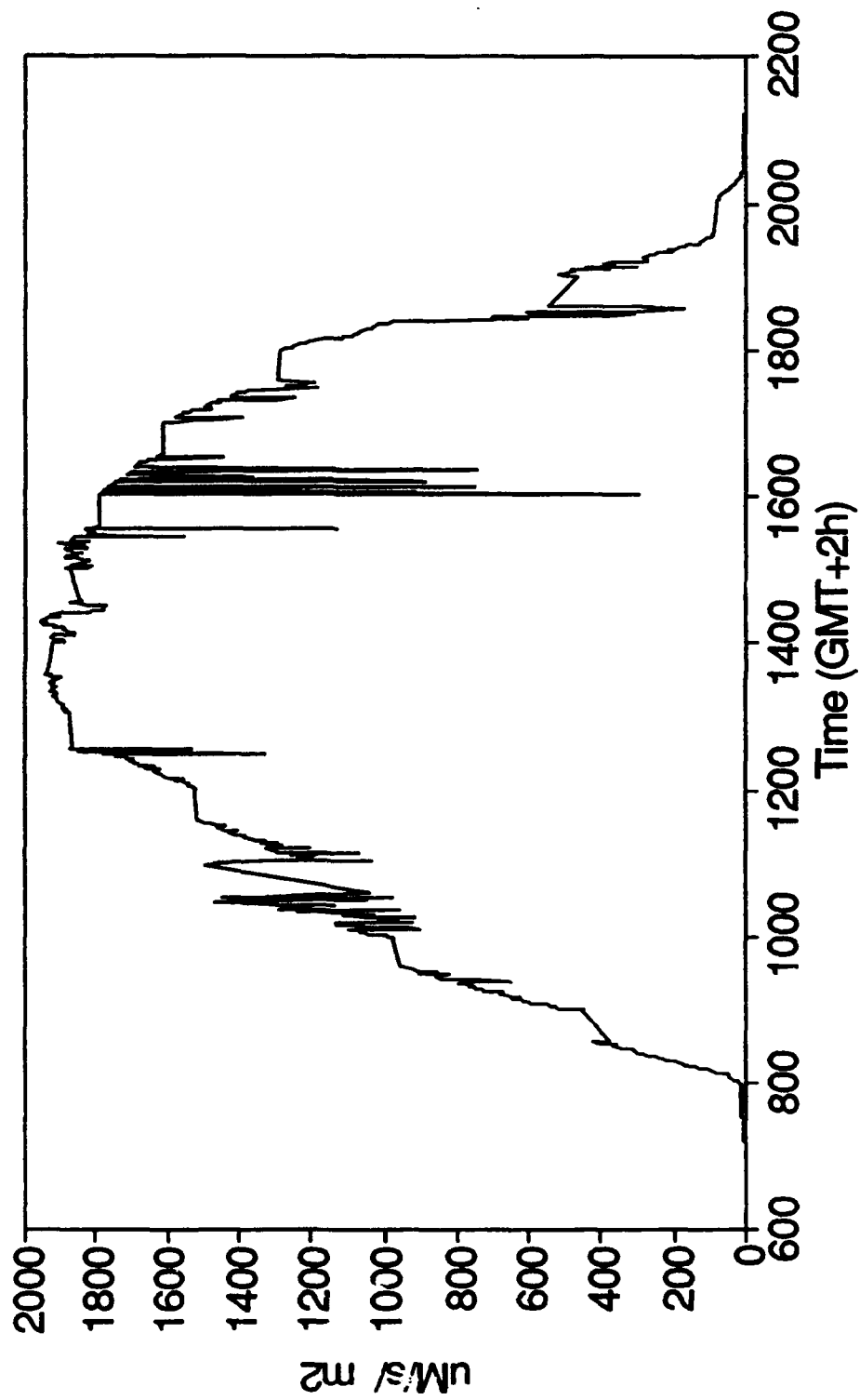
LICOR Apr 6

Total irradiance = ?



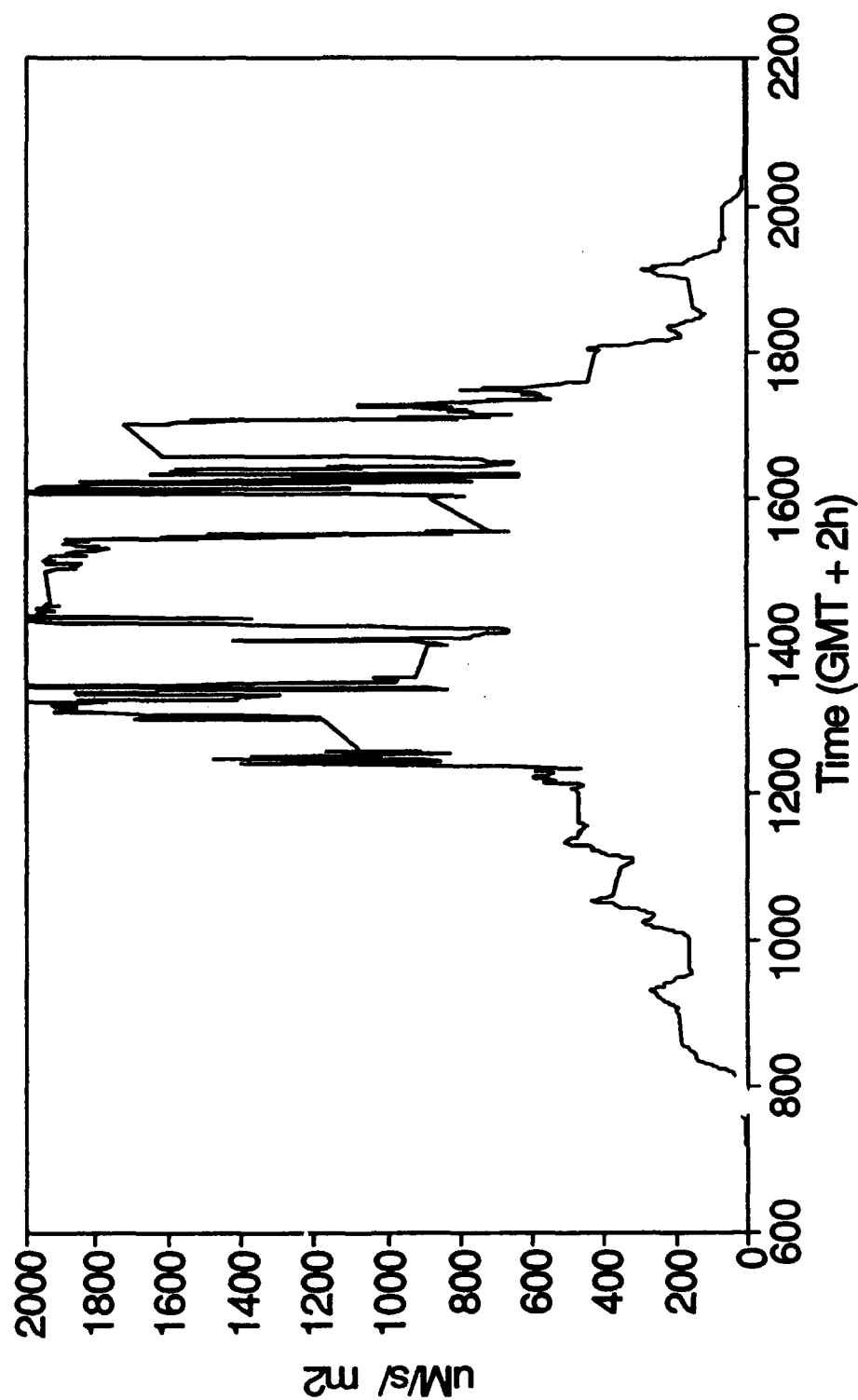
LiCOR Apr 7

Total irradiance = 5.34 E 07

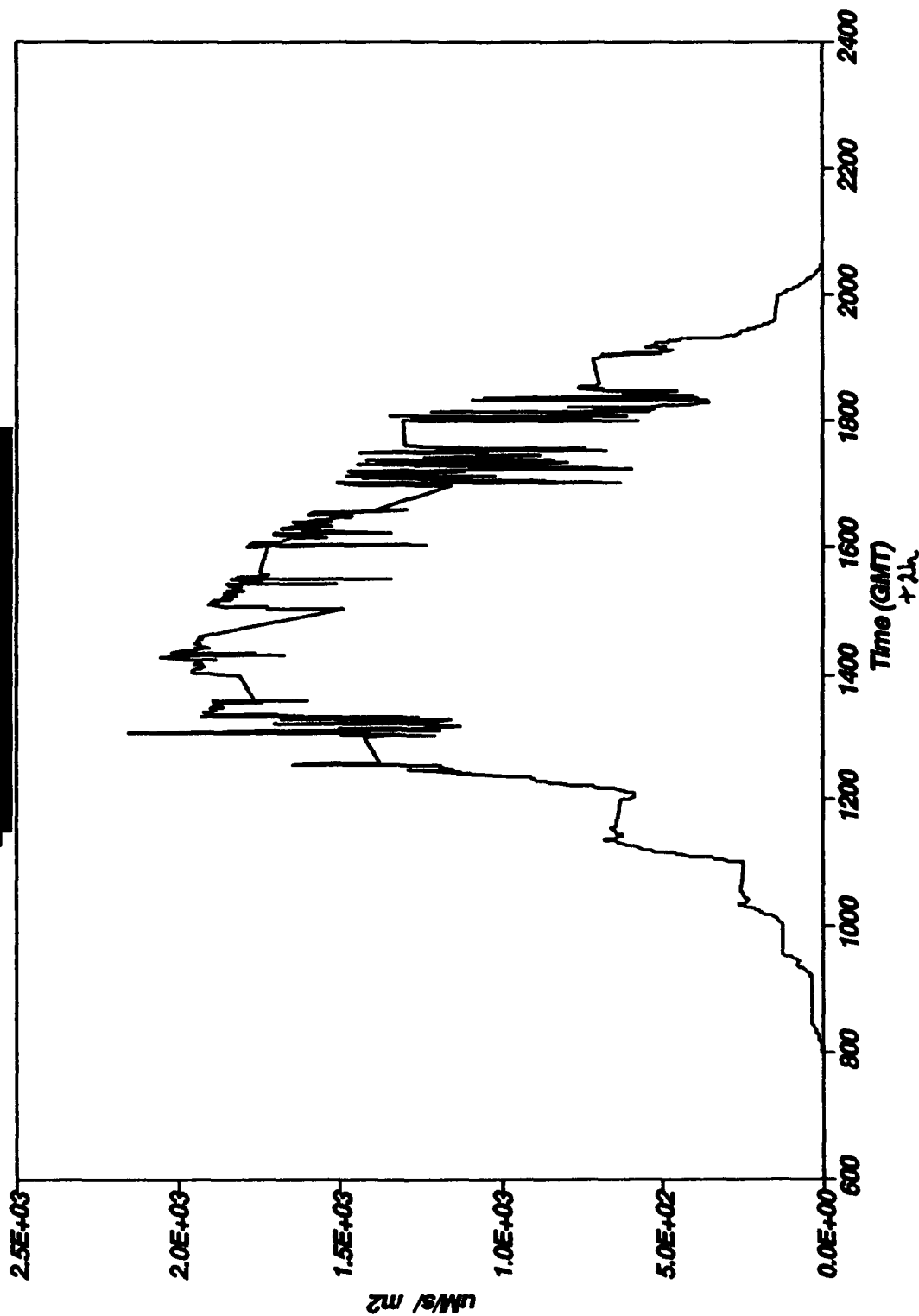


LICOR Apr 8

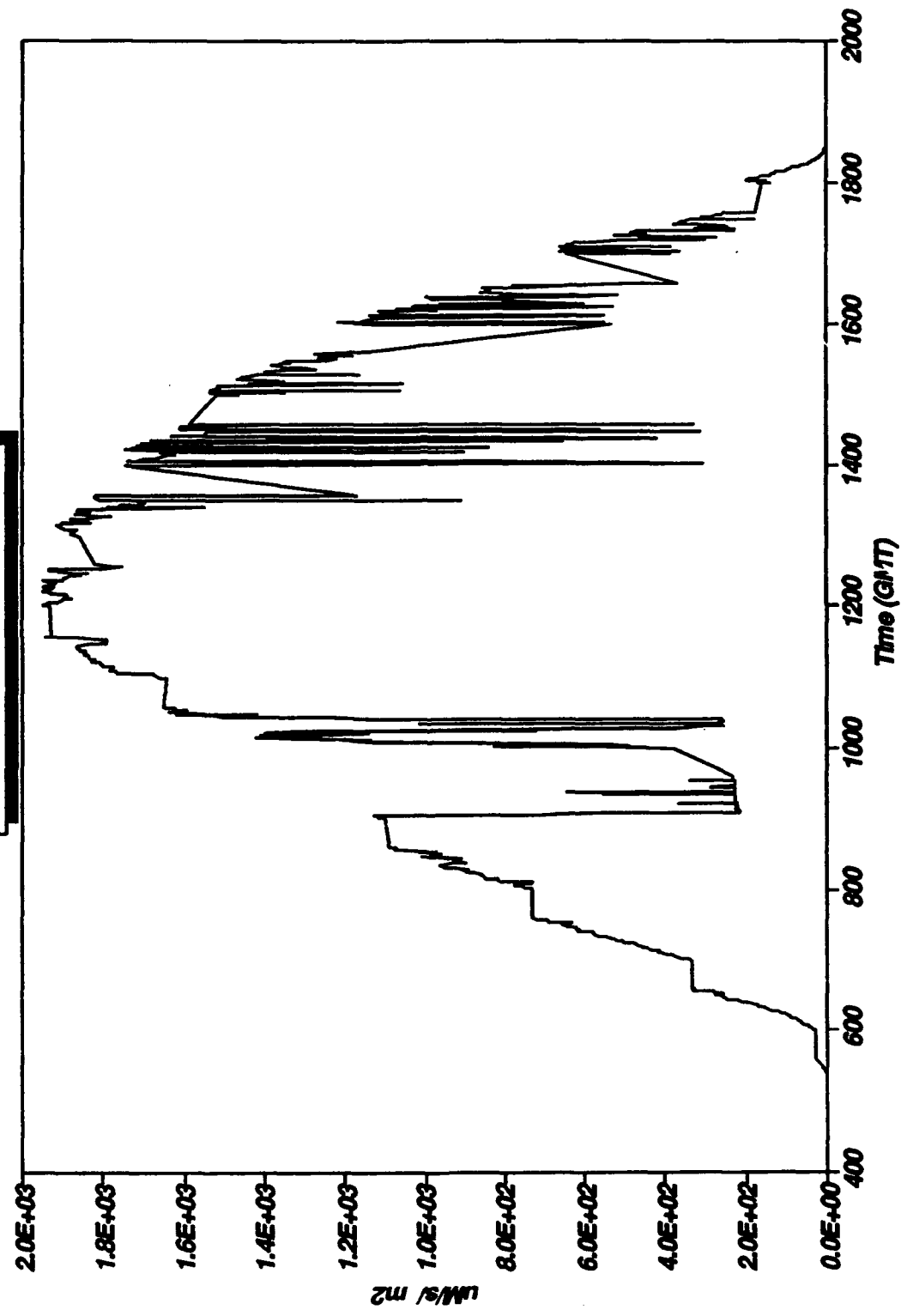
Total irradiance = 3.13 E 07 uM/ m2



LICOR Apr 9 STA 6
Total Irradiance = 3.89 E 07 uM. m2

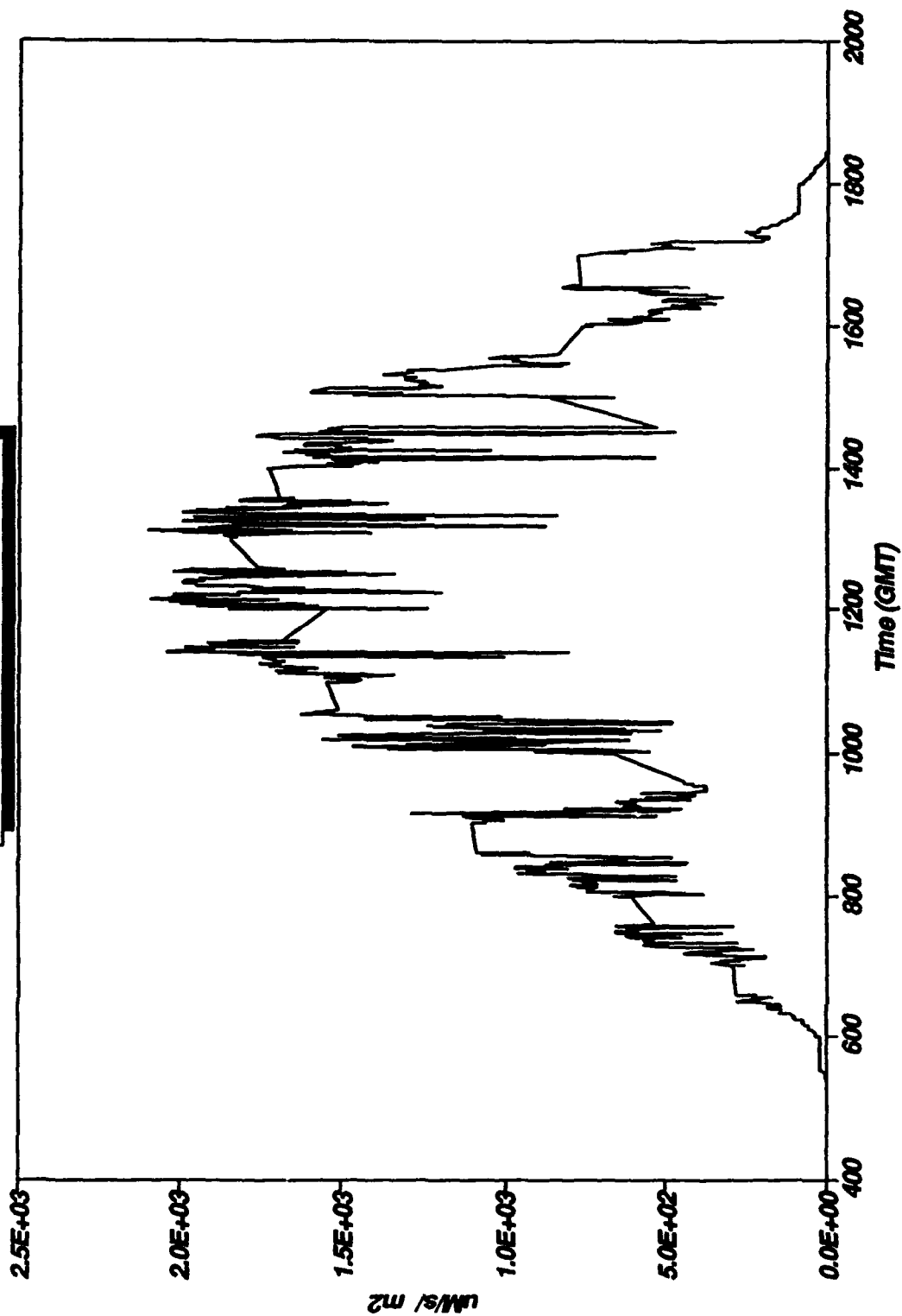


LICOR Apr 10 STA 7
Total Irradiance = $4.53 \text{ E } 7 \text{ uW/ m}^2$



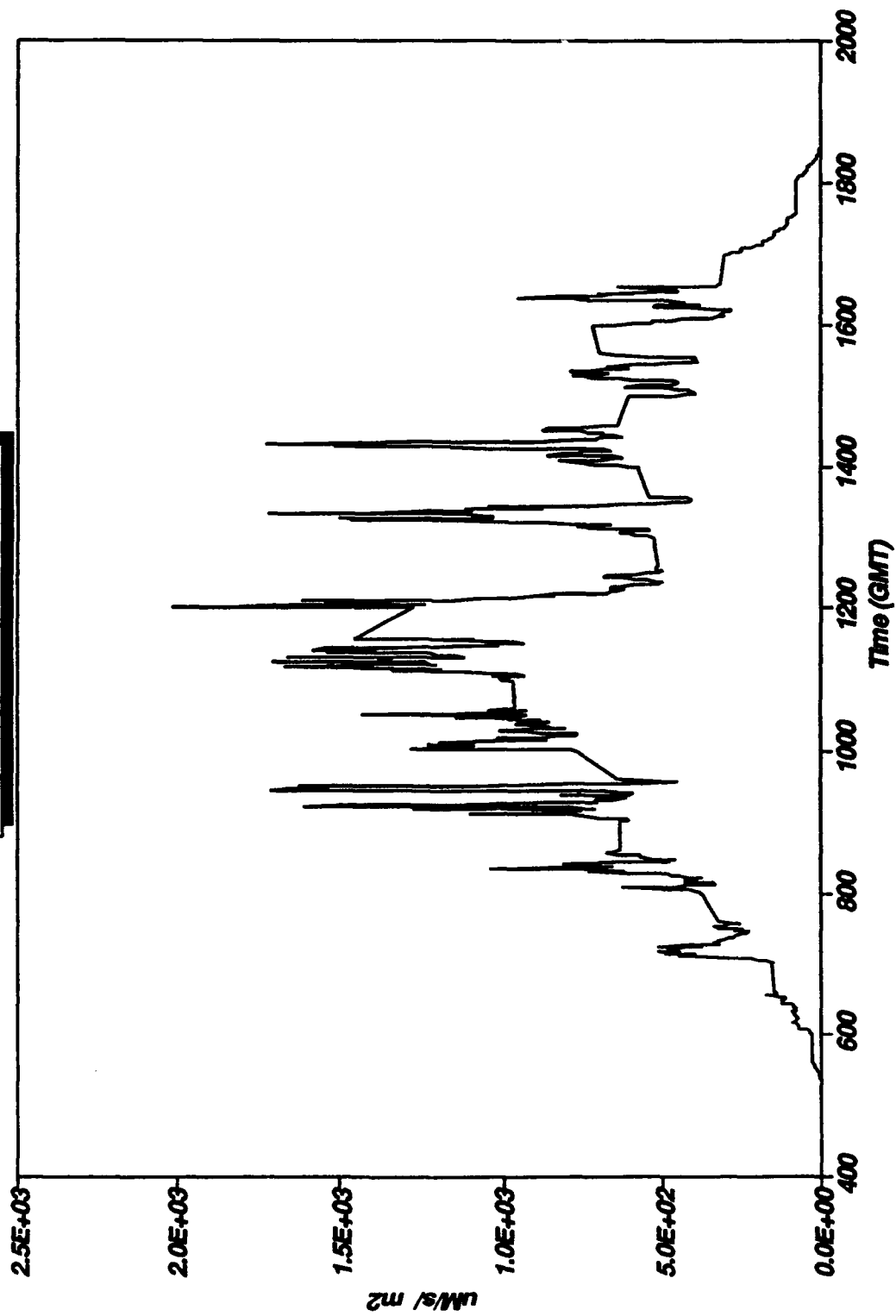
LICOR Apr 11 STA 8

Total Irradiance = $4.16 \text{ E } 07 \text{ uM/ m}^2$

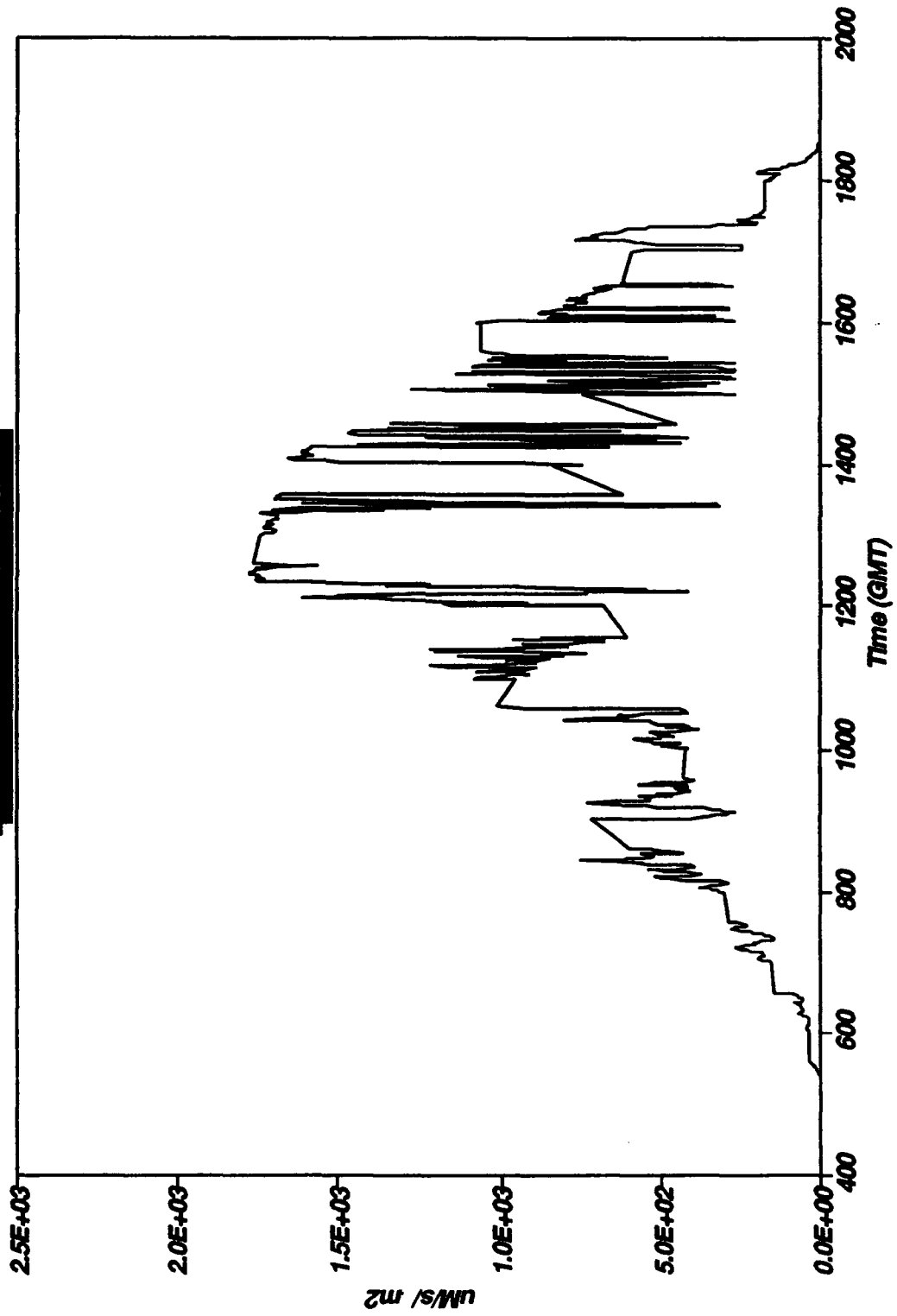


LICOR Apr 12 STA 12

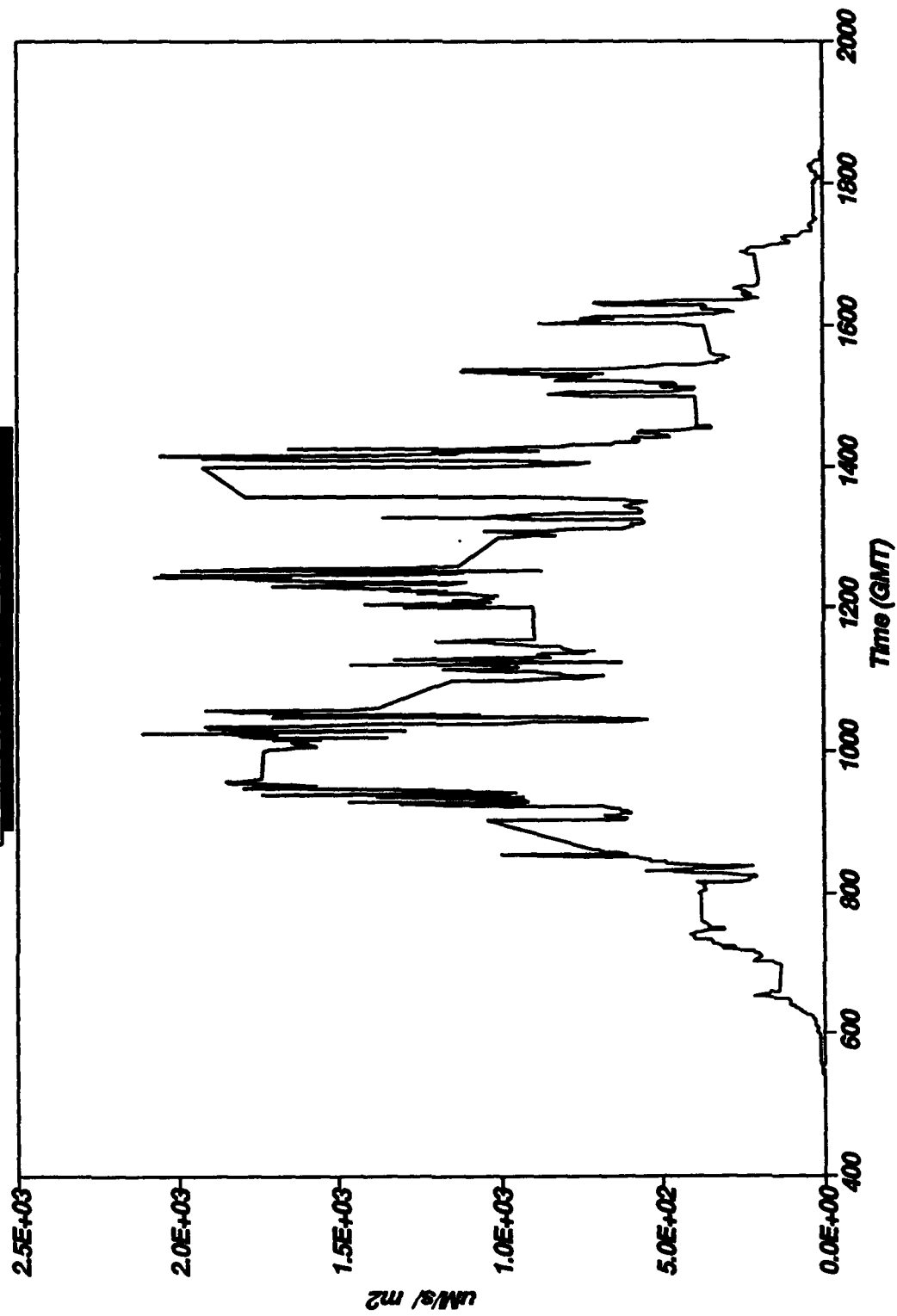
Total Irradiance = $2.77 \text{ E } 7 \text{ uW/ m}^2$



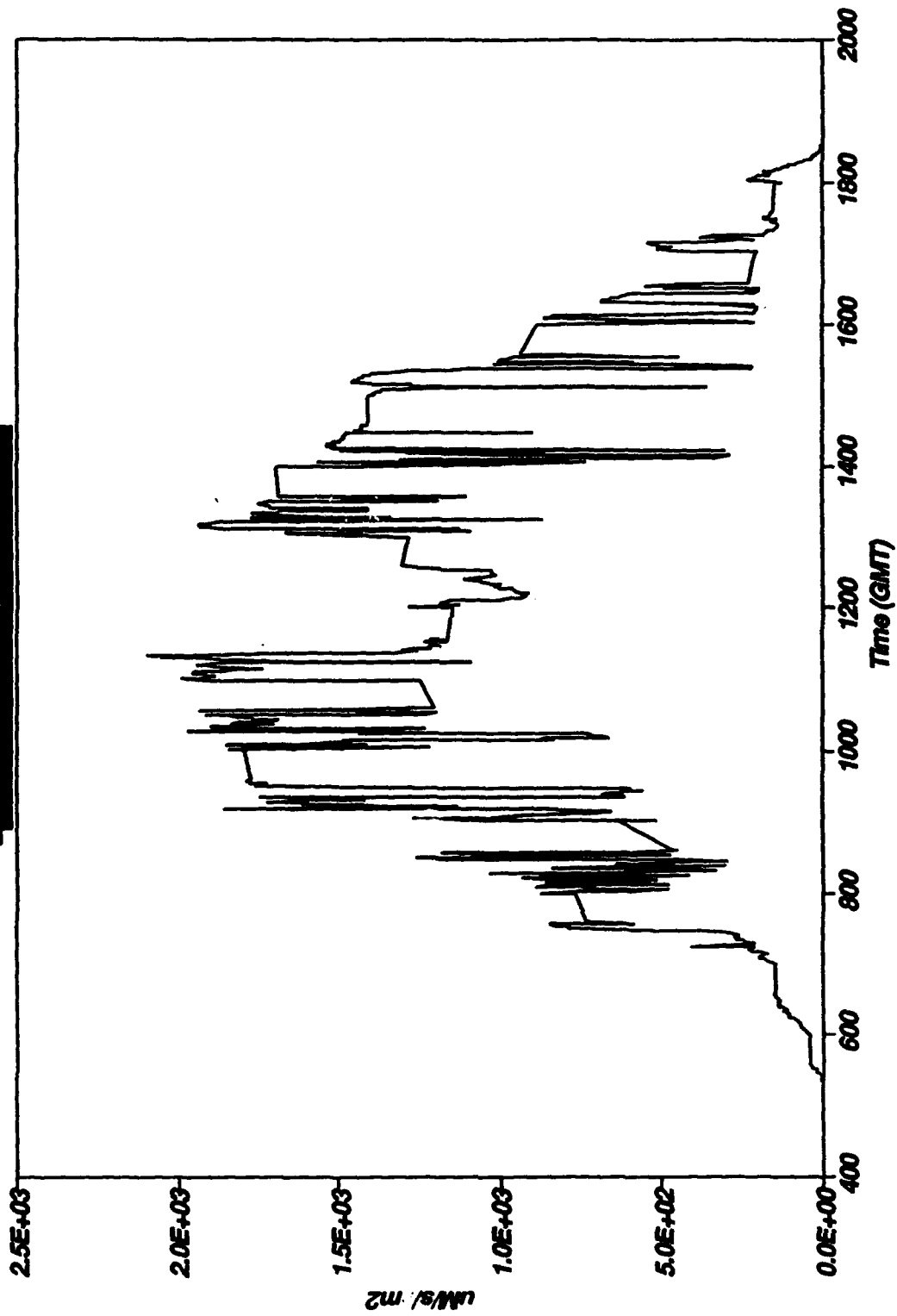
LICOR Apr 13 STA 12
Total Irradiance = $3.14 \times 10^7 \text{ uM} \cdot \text{m}^2$



LICOR Apr 14 STA 12
Total Irradiance = 3.01 E 07 $\mu\text{M}/\text{m}^2$

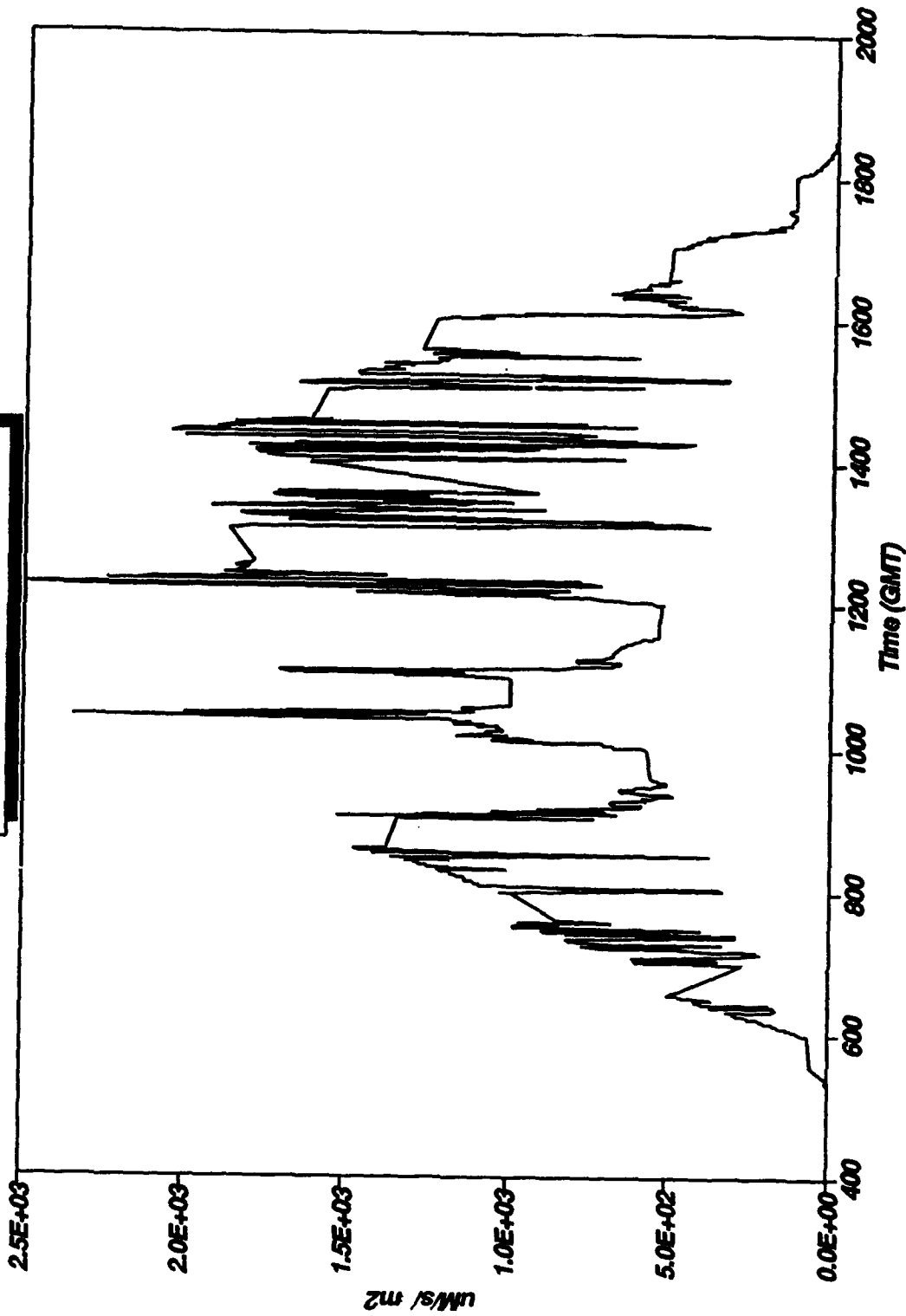


LICOR Apr 15 STA 12
Total Irradiance = 4.01 E 07 $\mu\text{M} \cdot \text{m}^2$

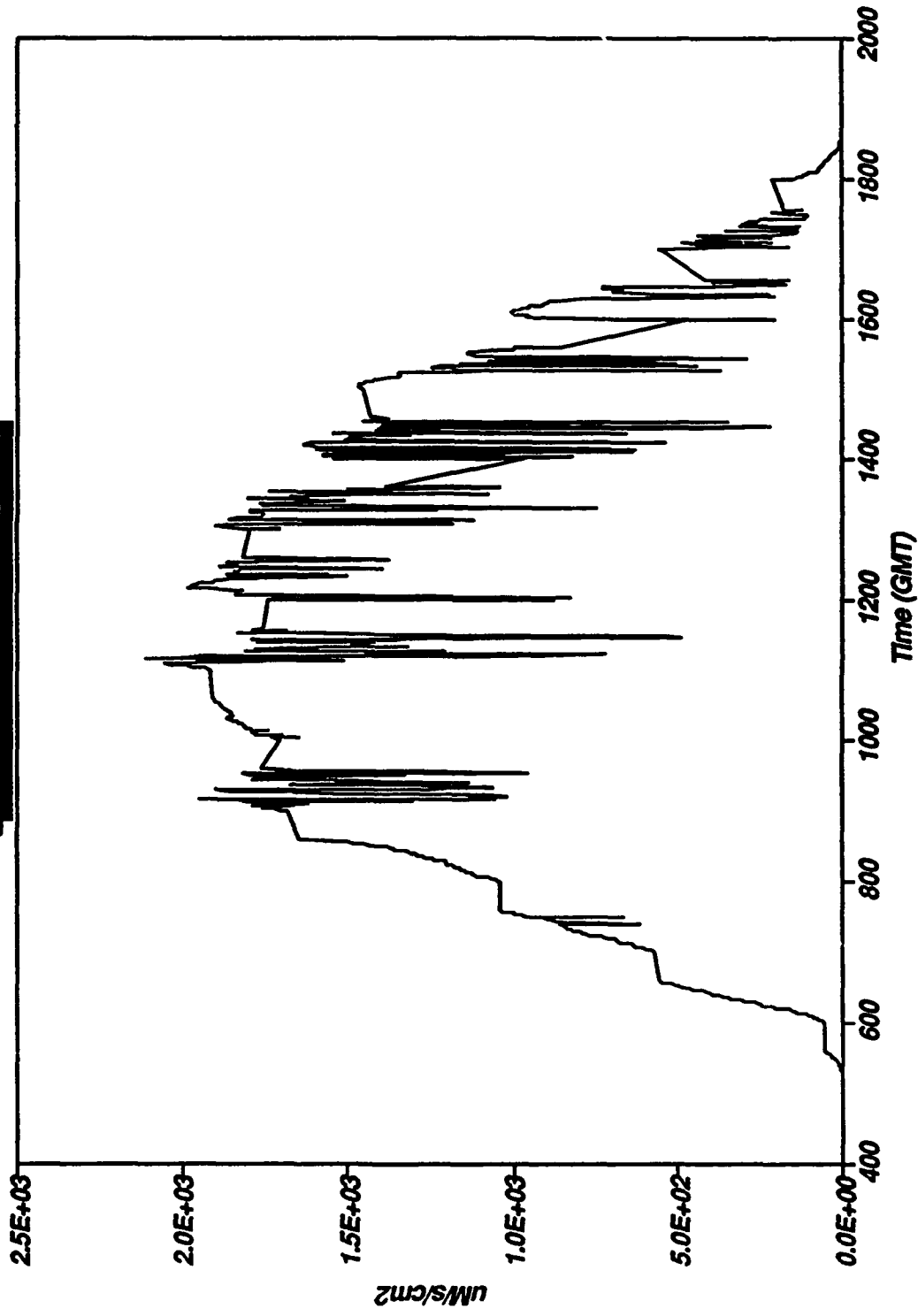


LICOR Apr 16 STA 12

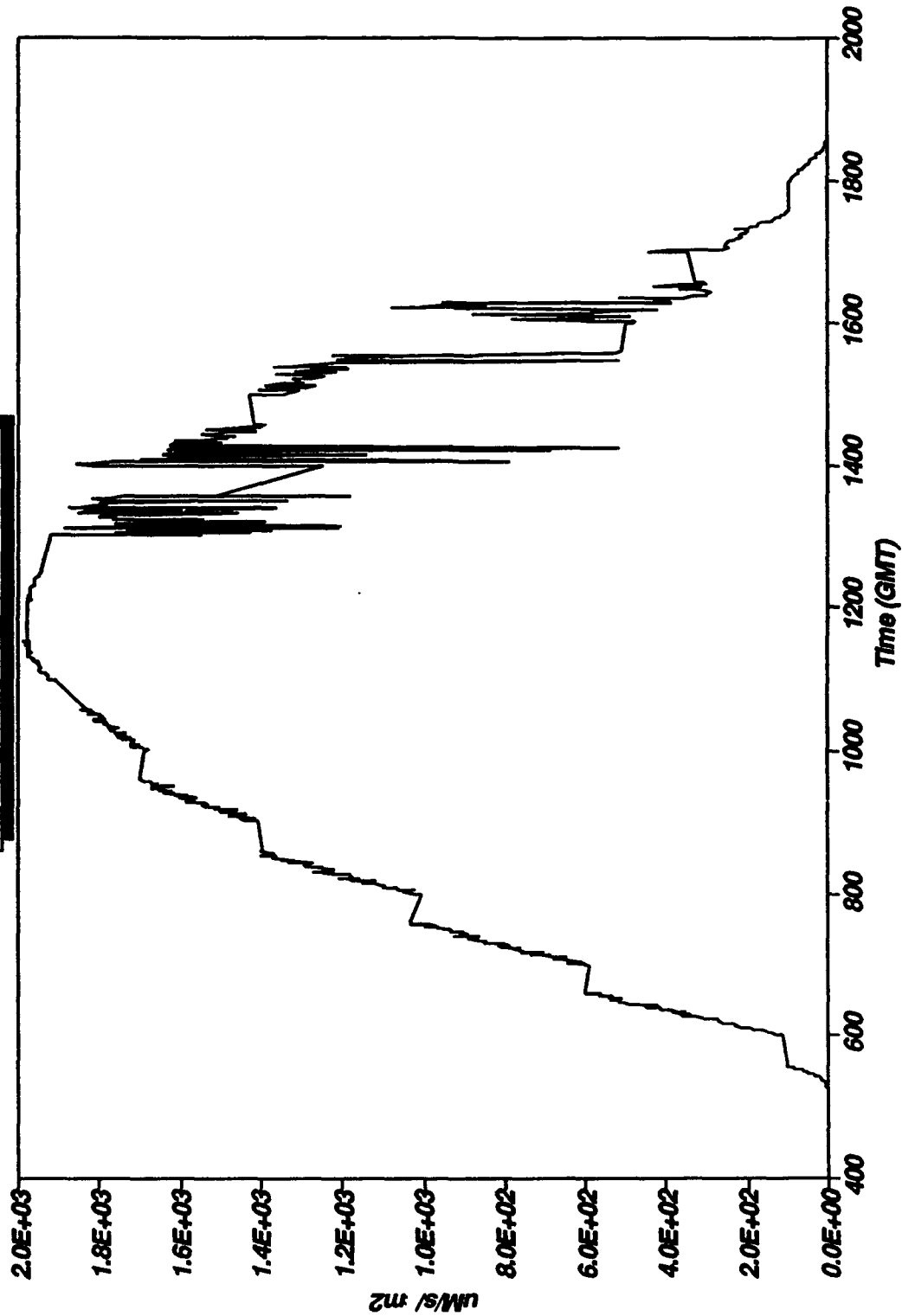
Total Irradiance = $3.83 \text{ E } 07 \text{ uM}^+ \cdot \text{m}^2$



LICOR 17 Apr STA 10
Total Irradiance = $5.0 \text{ E } 07 \text{ uW/cm}^2$

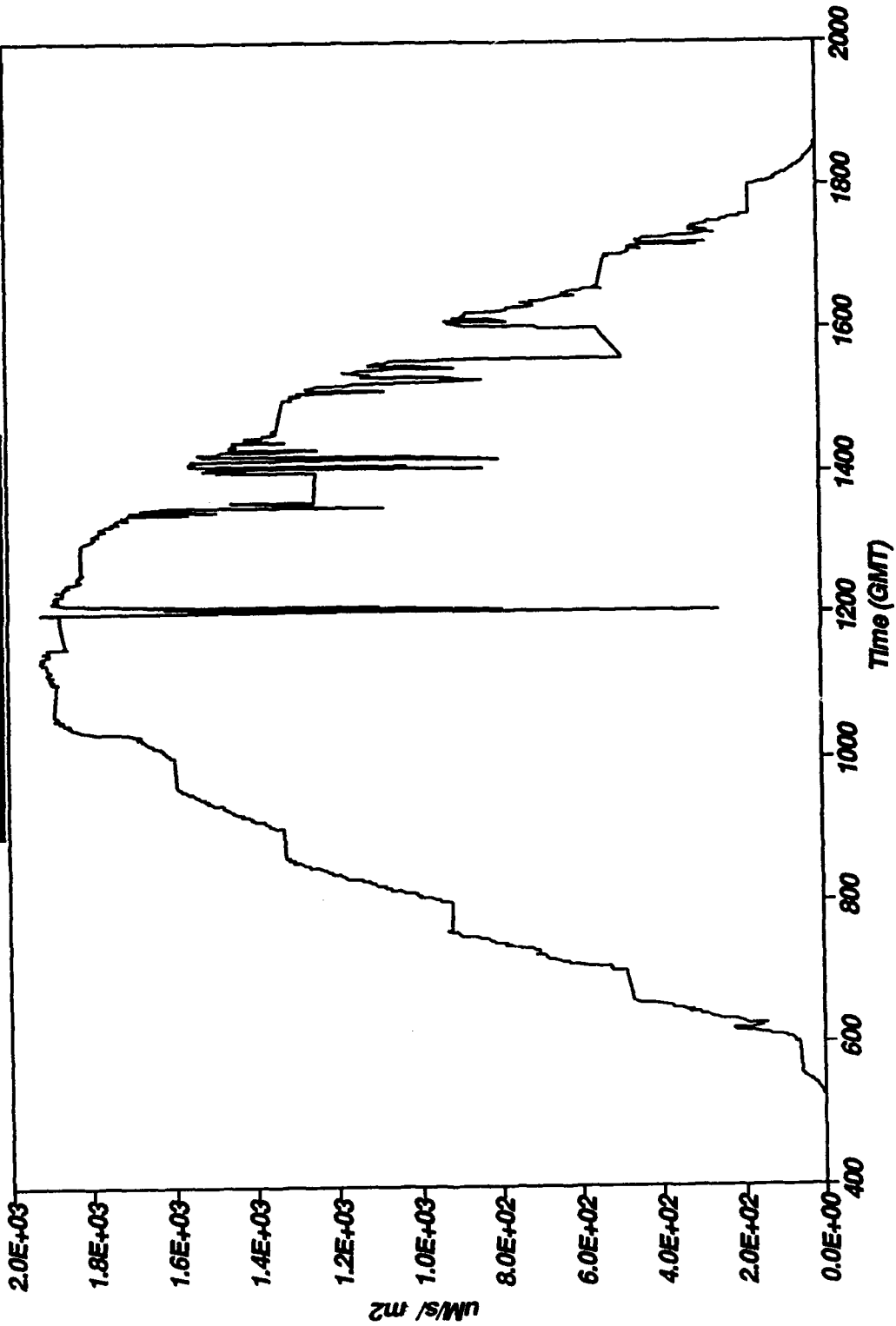


LICOR 18 Apr STA "13"
Total Irradiance = 5.23 E 07 $\mu\text{M}/\text{m}^2$

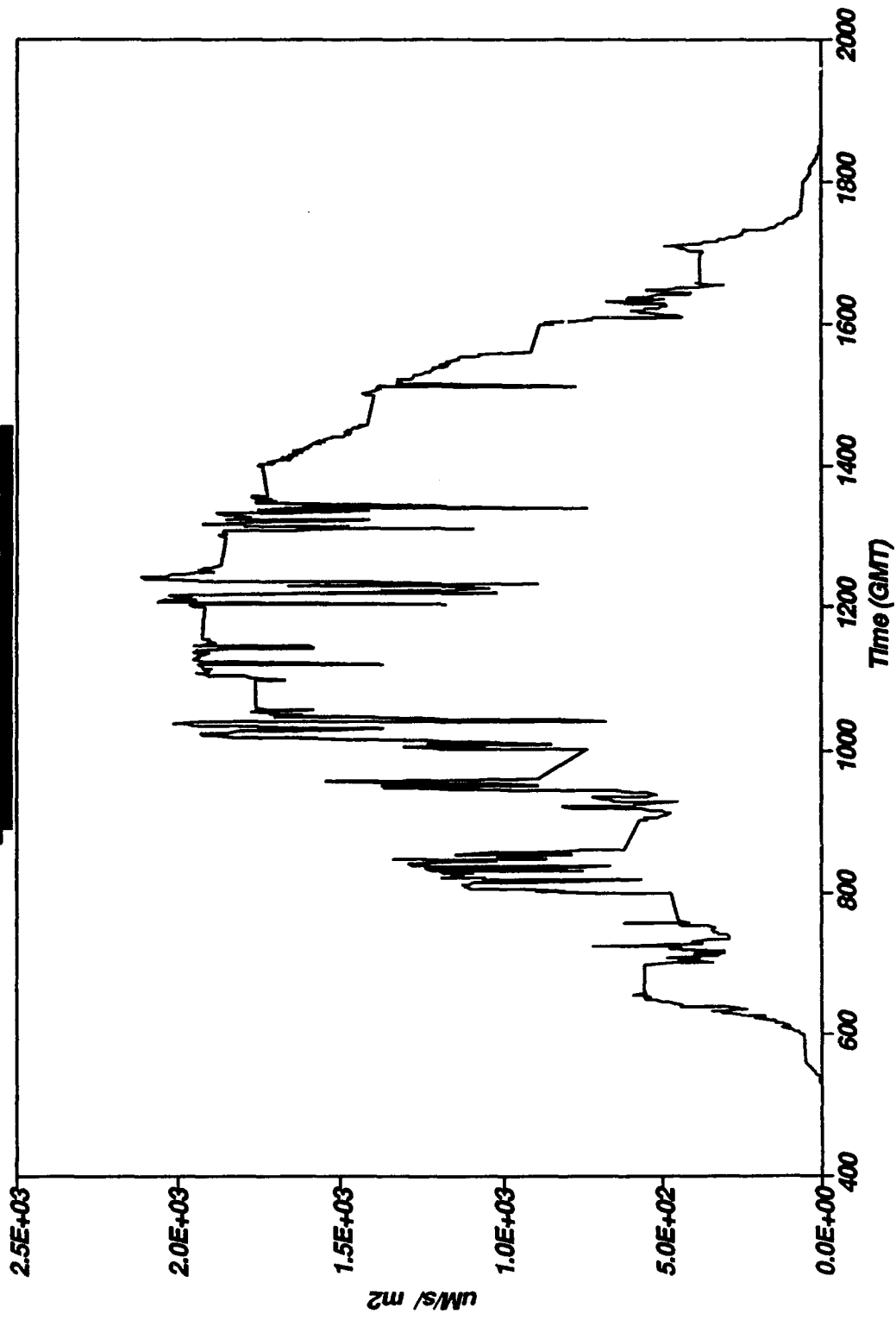


LICOR Apr 19 STA 15

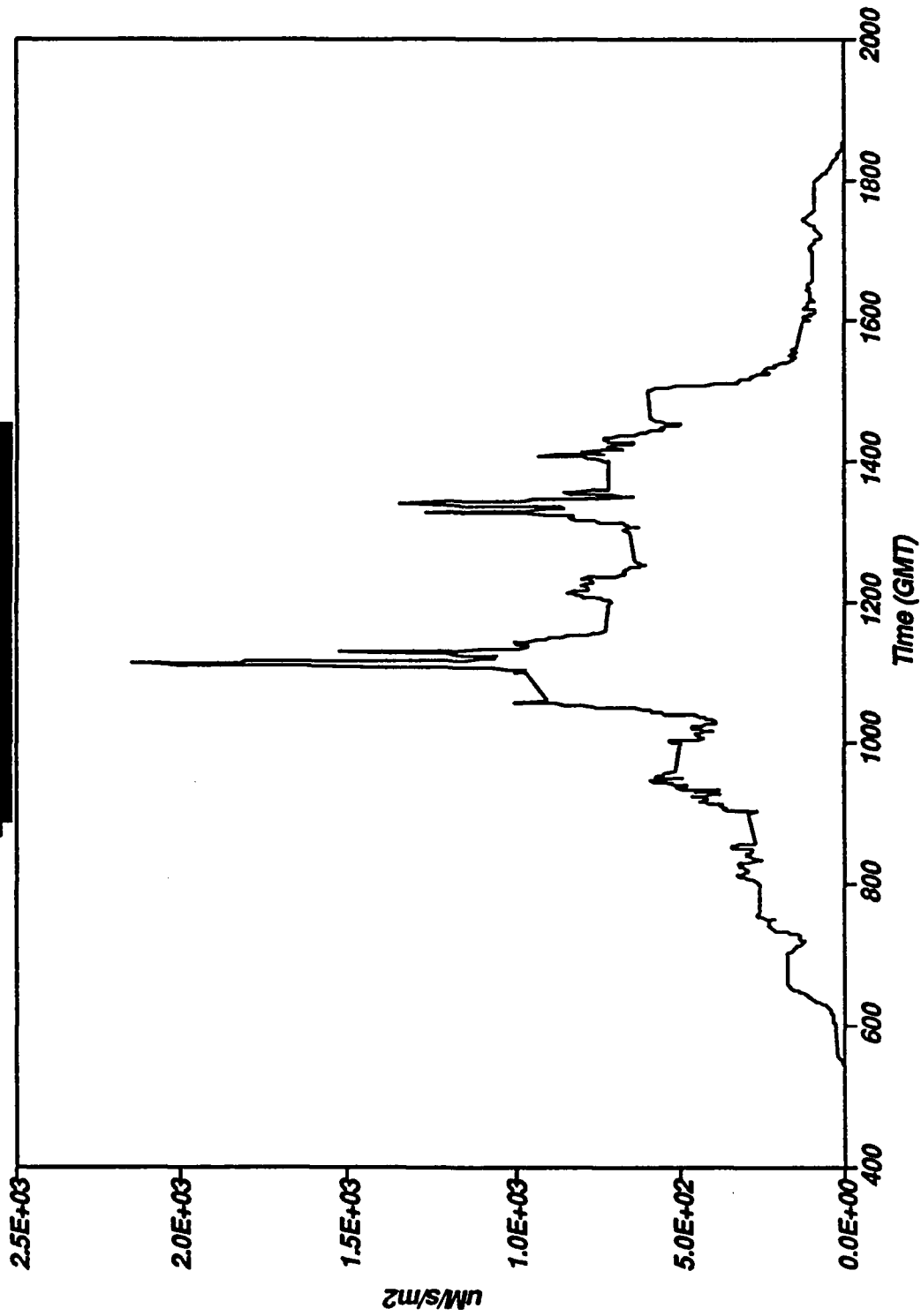
Total Irradiance = $5.07 \text{ E } 07 \text{ uW} \cdot \text{m}^2$



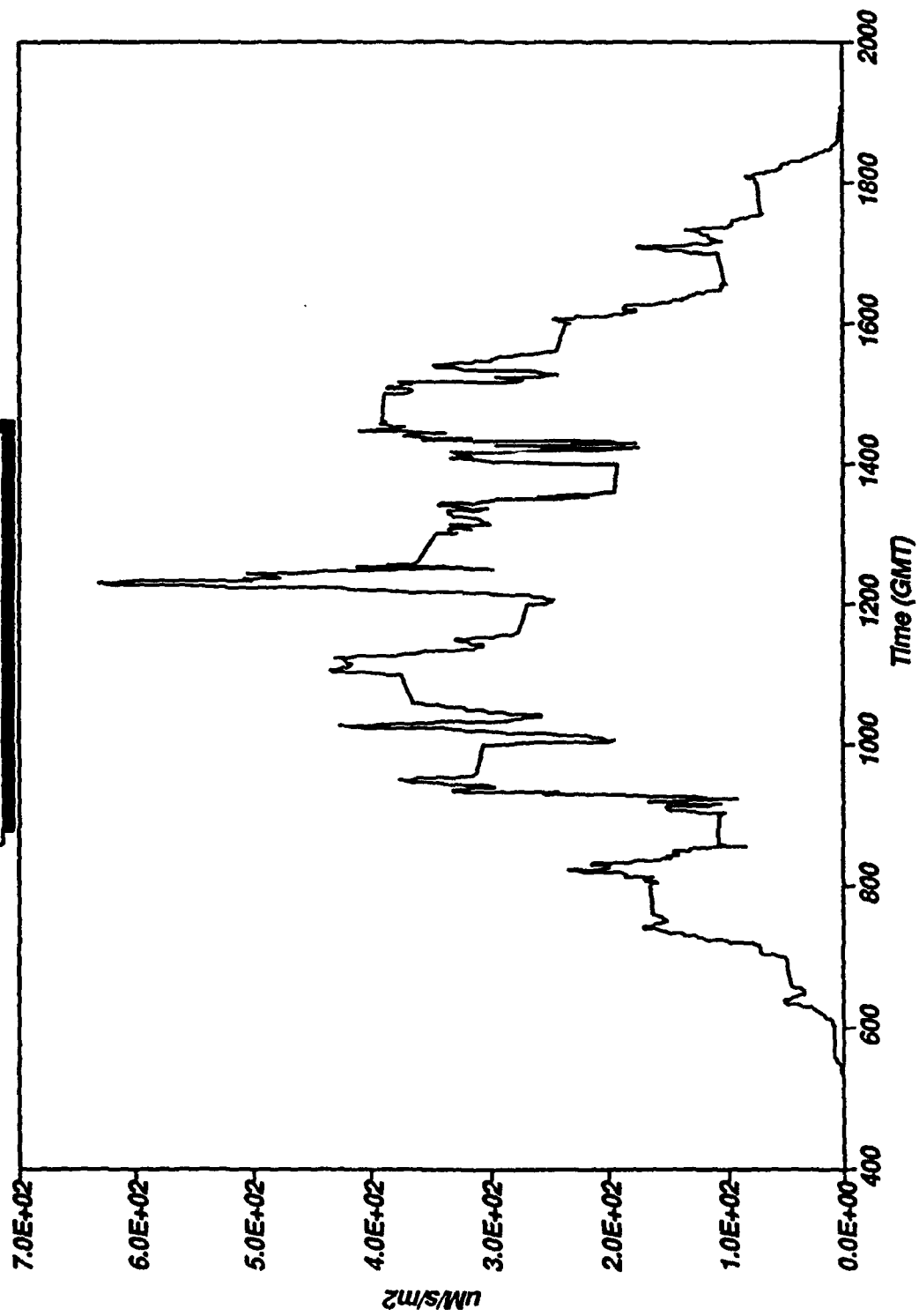
LICOR Apr 20 STA 15
Total Irradiance = 4.06 E 07 $\mu\text{M}/\text{m}^2$



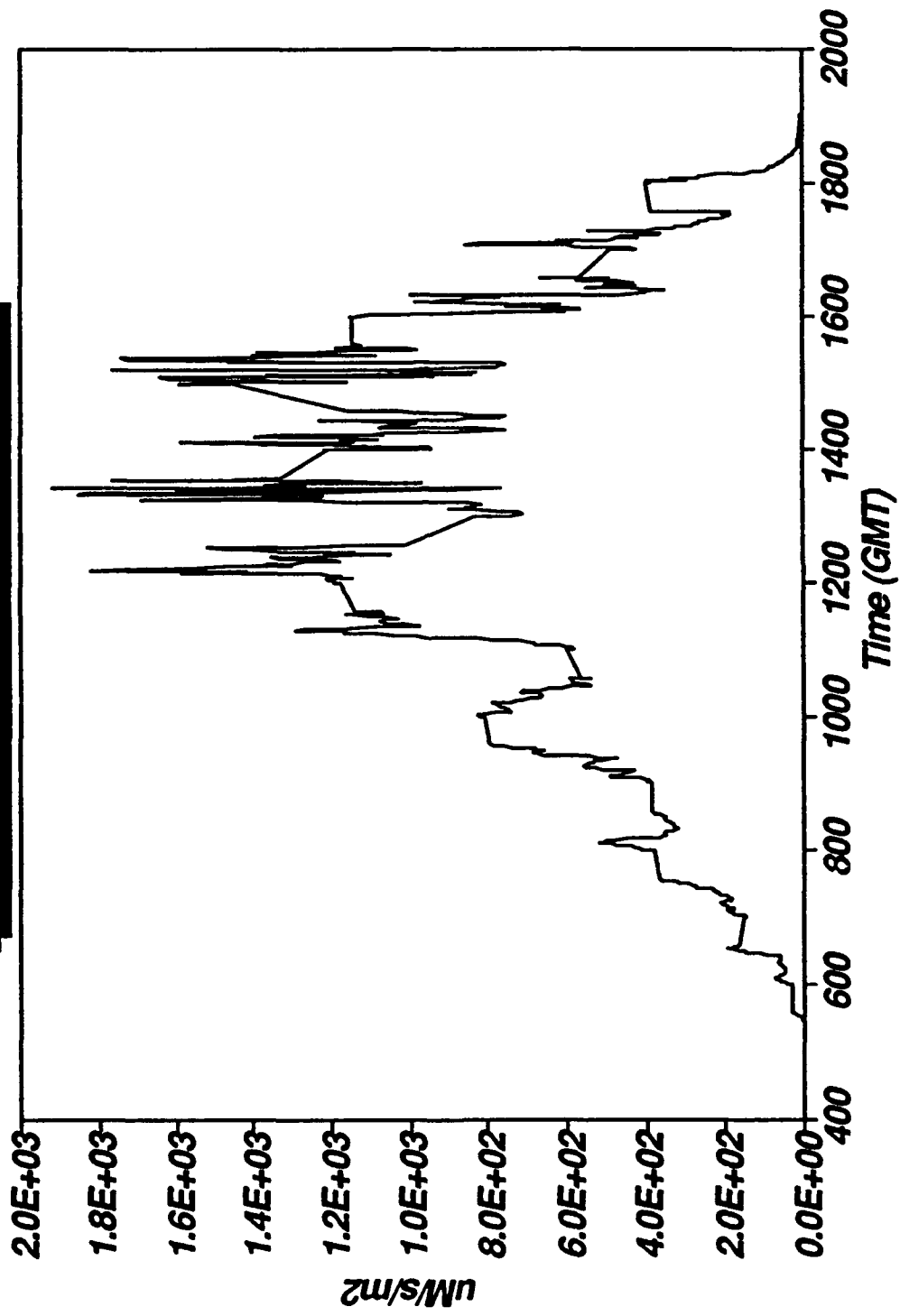
LICOR 21 Apr STA 16
Total Irradiance = 1.97 E 07 uM/m2



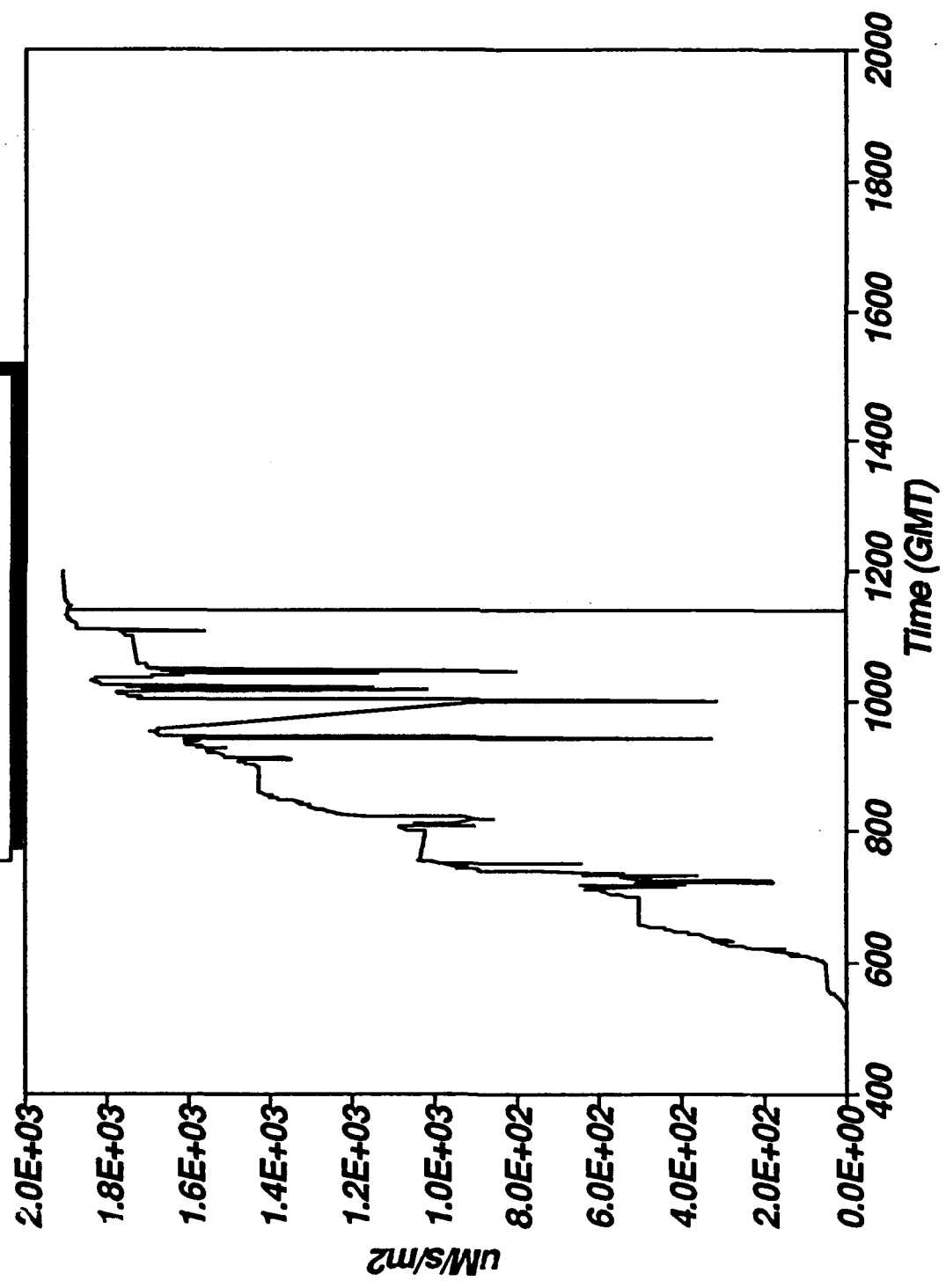
LICOR 22 APR STA 17
Total Irradiance = 1.02 E 07 uM/m2



LICOR 23 APR STA 2
Total Irradiance = 3.16 E 07 uM/m2



LICOR 24 APR STA 1



**Appendix E - Distribution and Taxonomy of Zooplankton in the Alboran Sea and
Adjacent Western Mediterranean: A Literature Survey and Field Guide. by
Laurence P. Madin**